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DEVELOPMENT DIGEST

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REMOTE SENSING

BLACK AND WHITE BAND 7 LANDSAT IMAGE OF MOUNT KILIMANJARO IN TANZANIA. VEGETATION FORMS THE LIGHT COLORED RING AROUND THE MOUNTAIN. THE TOP OF THE EXTINCT VOLCANO, LACKING VEGETATION, APPEARS DARK. THE VERY WHITE OBJECTS ARE CLOUDS HOVERING OVER THE SUMMIT. A LARGE AGRICULTURAL FIELD AND A RESERVOIR APPEAR ON THE LOWER CENTER OF THE IMAGE. (PHOTO: EARTH SATELLITE CORPORATION)

Space Technology for Development

John K. Wilhelm

[Space-age technology in the form of remote sensing methods can be useful in providing new ways of dealing with familiar problems. Communications, natural resource exploration, and disaster assistance are specific uses of remote sensing that have proven to be very useful.]

Three recent episodes illustrate how space-age technology touches the lives of people in developing nations: 1) In India, villagers are getting instructions via television on how to grow more and better crops, how to preserve the harvest with less spoilage, how to prepare food for better nutrition, etc. The sounds and sights reaching them originate with the nation's best teachers and leading authorities, speaking from centers hundreds of miles away. Transmission takes place via a U. S. communications satellite orbiting miles above them. 2) For no apparent reason, the fish in a river in Zaire had been dying. Worried villages had to carry water from wells as much as 30 kilometers away because they could not drink the river water. But with the aid of images received from the "Landsat" satellite passing overhead, analysis found that the source of the pollution was a diamond processing plant far upstream. They took action which is restoring the river to its earlier condition. The fish are returning; the villages again have clean, drinkable water. 3) An airplane flies high above a region of Guatemala which has been stricken by a severe earthquake. Within hours disaster relief officials study high-resolution photographs taken from the plane. With the help of these pictures, disaster specialists can assess the damage, set pri-

Mr. Wilhelm is with the U. S. Agency for International Development (AID) and directed the AIDSAT project.

orities, plan relief activities and determine the kinds and quantities of emergency supplies required.

In each instance, the desired result could not have been achieved as well or as quickly by any other method than the space-age technology that was employed. For many purposes this new method can do the job not only faster but less expensively, and with fewer undesirable side-effects. Sometimes space-age technology is the only feasible way.

Communication Via Satellites

North America's communications network, built over the past 100 years, is the investment of four generations. Arduous labor has brought forth millions of kilometers of wire and cable crisscrossing the continent and crossing under the oceans to its east and west. For other nations it has been equally slow and costly to build land-based communications systems across mountains and valleys, rivers and swamps. The enterprise involves a massive investment in human labor and economic resources.

Now, it is often possible to bypass much of this expensive time-consuming communications structure and look to space-age technology for many kinds of communications. Every year, new, more sophisticated, less expensive satellite communications systems are inaugurated. While the price of nearly everything else has been rising, global inflation has not been able to keep the price of communications from falling. Most telephone calls between continents cost less today than at any earlier time. Satellites transmit conversations, television programs, telegrams and other communications between distant points on the earth with greater reliability and less cost than ever before.

Satellites have in recent years been used to transmit educational programs for children and adults. Physicians give medical examinations to patients via television, observing the patient's appearance, viewing the inside of his mouth and throat, noting a grimace of pain--taking advantage of other aspects of non-verbal communication which is so vital in medical diagnosis. Many nations now possess satellite communications stations linking them to a global network. On July 8, 1976, Indonesia became the world's fifth nation, joining the U.S., USSR, Canada, and Brazil, to have its own domestic communications satellite. For smaller countries than these, however, access to some of the channels in a regional satellite can provide ample communications facilities.

The Genesis of Project AIDSAT

The ATS-6--Applications Technology Satellite Number 6--already has established for itself an unprecedented record of service in widely separated parts of the earth. ATS-6 is in a path in which it completes one orbit every 24 hours, thereby keeping pace with the earth's own rotation.

As seen from the earth's surface, ATS-6 appears to stand still in the sky. The United States used the satellite from May 1974 until May 1975 for an "education-at-a-distance" experiment in which lessons were televised into classrooms in secondary schools in communities isolated by mountainous terrain in portions of the western United States where specialized education was not readily available. The satellite was also used for medical services in Alaska, the northernmost U.S. state, where villages which have no physicians are sometimes cut off from distant cities by severe winter weather conditions. Via satellite television, physicians at city medical centers were able to talk to, see, and even "examine" patients in emergency situations in the villages. Similarly, the satellite was used for medical education and information exchanges among physicians at medical colleges and hospitals.

In May 1975 the satellite propulsion unit was started by radio control from earth, and ATS-6 moved eastward from its "station" above the Galopagos Islands to a new location above Lake Victoria in Kenya. While hovering for a year over that location, ATS-6 was used by the Government of India to televise educational programs into approximately 5,000 villages. In August, 1976 Project AIDSAT began when the ATS-6 was moved slowly toward South America. In the next three months special educational broadcasts, as well as live intra-country and international two-panel discussions, were undertaken in a series of developing countries.

What makes Project AIDSAT technically possible is the sophistication of ATS-6. Earlier communications satellites required very large and complex earth installations--massive antennas costing hundreds of thousands or even millions of dollars--and were far too heavy and bulky for fast transportation and installation at different locations. ATS-6 is far more powerful than the satellites used by many countries for commercial communications. It can receive from and transmit to relatively small, simple, inexpensive earth stations. Thus, teams of technicians can transport on a single aircraft the equipment required to transmit and receive color television programs. This equipment can be quickly set up to be used for the program in one country, and taken down again for movement to the next country. By October 1976, all the countries participating in Project AIDSAT had been visited, and Project AIDSAT came to an end. The ATS-6 then resumed communications experiments in the Western Hemisphere.

Resource Assessments via Landsat

Two unmanned satellites with sensors especially designed for observing and reporting on the condition of the earth's surface transmit their images of our planet. Each satellite, called Landsat, orbits the earth 14 times each day, sending back images of the surface below. [Landsat is described in detail in a later article.] The pictures produced by Land-

sat reveal information about crops, foliage, geological structures, water conditions and distribution, man-made and natural features of a region, and a host of other aspects of earth. Some examples:

o Using Landsat imagery, investigators in Thailand found that the nation's timber reserves were a third less than had been assumed.

o Mapmakers in Bolivia discovered rivers had changed course. Based upon space-gathered observations, they made cost-saving alterations in proposed highway and pipeline construction plans.

o Bolivia also used Landsat observations to remap the country and inventory its natural resources--doing so far more quickly and inexpensively than could have been done by other methods.

o In Zaire, Landsat analysts discovered a freshwater lake not shown on maps. Discoveries of previously unknown fresh water sources through Landsat can materially affect economic planning and development in many regions of the world.

o In Iran, a Landsat investigator established the presence of fresh water under a salt flat.

o The movement of sand dunes is being monitored by Landsat investigators in Egypt. The information gained is being evaluated for use in planning construction and development which is less vulnerable to inundation by the rolling dunes whose course scientists may now begin to predict.

o Landsat imagery has helped to find remote vegetation hospitable to the tsetse fly, and conditions favorable as breeding grounds for malaria-carrying mosquitoes for attention by pest control crews. Elsewhere comparisons of seasonal or other periodic changes as recorded in successive Landsat observations have made possible the charting of floods and erosion to assist land use planners.

Landsat may help increase agricultural production by identifying potentially fertile soils; by indicating favorable growing conditions; and detecting certain plant diseases and insect infestations. This is possible because diseased crops reflect a different radiometric "signature" for Landsat's sensors than do healthy crops. Efforts to use Landsat for these purposes are still in the pioneering stages, but offer considerable promise for the future. AID hopes to participate in the design of future Landsat remote sensing satellites and to incorporate in them capabilities which are specifically tailored to assist developing nations in their efforts to assess their resources and improve their lives.

Disaster Prediction and Assistance

Natural disasters are among man's universal tragedies. As man's

numbers grow, disasters affect ever more people and require ever more organized and intensive relief efforts. While man cannot eliminate natural disasters, the number of victims and damage to property can be greatly reduced with available technology for preparedness, communications and rescue. Space-age technology is providing tools and techniques for predicting and assessing disasters and giving assistance after they occur. Disaster forecasting techniques make it possible to plan for, rather than merely react to, disasters.

Earthquakes are one of the least understood causes of disaster, and satellites are contributing new knowledge. Recently, for example, images from Landsat revealed that a fault in the United States that had been thought to be only five kilometers long actually extended for 97 kilometers. (A geographical "fault" is a discontinuity in the earth's surface around which earthquakes tend to concentrate.) Followup aerial photos from an altitude of six kilometers gave geologists additional information. In addition, instruments now being designed and tested for strategic installation at fault lines will soon monitor very small fault line movements in the earth for possible prediction of earthquakes. "LAGEOS" is the name of a new satellite with high-quality optical prisms which reflect laser light beams back to fixed positions on earth. The time required for the round-trip of the beams is converted into extremely accurate measurements of distance. If the distance from the laser station to the satellite changes between periodic measurements, even very slightly, scientists know that the earth's crust has moved. Without the satellite, which holds a fixed position independent of earth movements, it was difficult to define such movements with instruments placed on the ground.

Weather is still the most frequent cause of national disasters. As a hurricane swirls at sea, a U.S. weather satellite 36,000 kilometers above the earth's surface photographs it at regular intervals and measures its wind speed, temperature and direction of movement, and the condition of the sea and air around it. This information, when processed by computers, can help meteorologists predict a hurricane threat to inhabited regions. Additional information obtained from aerial photographs and radar probings supplement the satellite's overview. Day and night the tracking of the storm continues. When the computer print-outs show that inhabited regions are threatened, an early warning is sounded and a well-planned program of precautions is set into motion. Food and fresh water are stored. Batteries are readied for use in the event of electric power failures. Hospital patients are moved to safer places. Every available resource is mobilized in a disaster preparedness plan for protecting life and property.

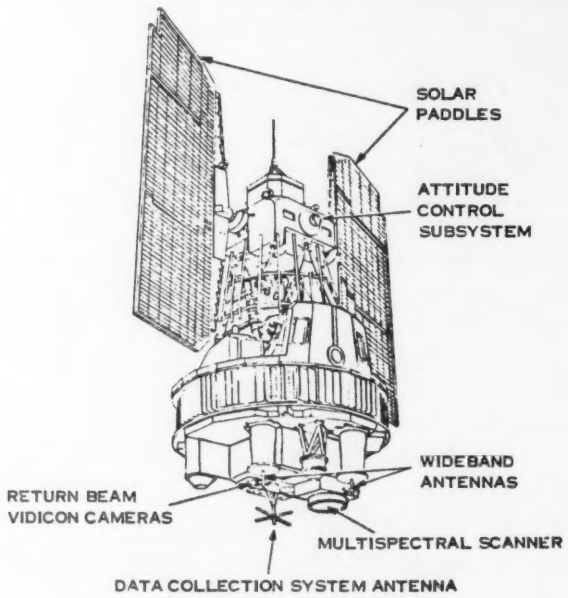
Floods are more readily predicted than storms. Six times each day automatic measuring instruments located in remote rivers, at sea coasts and on land take readings of water levels, tidal changes, rainfall and snow accumulations, and transmit them to a satellite passing above.

This information often helps weather scientists foresee floods long before they occur.

Volcanoes are important in some areas. Devices called "tilt meters" detect ground tilting which often precedes volcanic eruptions whose flow of molten rock destroys lives and property in many parts of the world. Information radioed by tilt meters via satellite to ground stations can give warning of impending disaster.

Similarly, electronic stations powered by solar energy in remote forest regions measure and transmit every few hours information on humidity, temperature, wind velocity and other factors affecting the spread of forest fires. Such information can be used to alert fire fighting crews and special observation teams in the air and on the ground to check for possible fire outbreaks, or chart the course of existing fires. No country can afford disasters. Every country can take part in the modern effort to lessen their devastating impact by joining with others in employing the best ways of dealing with them.

[Extracted from: AIDSAT: Space Age Technology for Development, a pamphlet published by the U. S. Agency for International Development, Washington, D. C., 1976.]



The Landsat Satellite

Remote Sensing in Brazil

Allen L. Hammond

[The Brazilian government has used data collected from satellites in gathering natural resource information for all of Brazil. Airborne radar has also been used to map the unexplored regions of the Amazon in Project Radam.]

Remote sensing by airplane and satellite is profoundly changing the way geologists, hydrologists, land-use planners, and other resource specialists go about their work. The benefits of this new capability promise to be particularly significant in the developing countries of the world that lack other means of surveying and assessing their resources. Nowhere is this promise clearer than in South America, where remote sensing techniques have already made important contributions or appear to be on the verge of doing so in more than half a dozen countries. Brazil began early and has the largest effort, but programs are also under way in Bolivia, Venezuela, Colombia, Chile, Peru, and Argentina. The results of these efforts include mineral discoveries, the first accurate maps for large portions of the continent, and a new capability to plan and monitor development activities.

In Bolivia, for example, analysis of Landsat photographs of a huge salt flat resulted in the discovery of brine pools containing extremely high concentrations of lithium and potassium; Bolivia is now considering commercial production. In Brazil, the agency charged with monitoring the development of the Amazon Basin is using Landsat images to enforce laws restricting the amount of tree-cutting and

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land-clearing done on private ranches, and radar maps to plan the location of new ranches and other facilities. In Chile, hydrologic maps based on satellite photos are being used to estimate water availability in arid regions of the country. Although the pace of research and the application of these new techniques have proceeded slowly in recent years, there are now indications of a rapid acceleration.

These results and the ongoing programs depend heavily on two remote sensing techniques, both developed in the United States: airborne radar, which permitted the mapping of otherwise impenetrable, cloud-covered jungle regions and hence the first systematic look at their resource potential; and satellite observing platforms, such as Landsat (formerly the Earth Resources Technology Satellite).

Brazil is the first developing country to have its own Landsat ground station, one of only four permanent stations outside the United States. Brazil can thus receive information from the satellite directly as it passes overhead every 18 days. The station is located in the south near São José dos Campos, the Brazilian aerospace center, and can provide Landsat images covering nearly all except the southernmost portions of the South American continent. Because of this, Brazil is now becoming a source of Landsat data and remote sensing expertise for other South American countries as well. But Brazilian interest in remote sensing techniques antedates Landsat.

Evolution of the Satellite Program

Brazil's space agency, the Instituto de Pesquisas Espaciais (INPE), has since its beginnings in 1962 been oriented to space applications, such as the use of satellites to broadcast educational programs to rural areas. According to Fernando Mendonça, INPE's former director and the person credited as the father of remote sensing in Brazil, remote sensing efforts began as early as 1967. At the time, however, there was little awareness of, or interest in, remote sensing in Brazil; laws governing resource exploration were prohibitive; and there was also considerable opposition from military officers concerned about aerial photos of strategic sites. INPE managed to get government permission for aerial surveys in a few limited areas with aircraft and sensing equipment loaned by the U. S. National Aeronautics and Space Administration (NASA). "Then we had something to show around," Mendonca says, and interest was generated. INPE had to train not only its own specialists but also the potential users of remote sensing data from other government agencies in such things as photo interpretation. In 1970 INPE acquired its own plane for aerial surveys, and in 1973, a Landsat terminal.

The Landsat program has now grown to be a major remote sensing effort with hundreds of customers for the data it provides and a substantial re-

search program. But the program has had a history of problems that are only gradually being resolved. The ground station and the associated processing equipment to produce photographs from the data radioed down from the satellite operated unreliably for the first couple of years, in part because film, replacement equipment, and other supplies had to come from the United States. "It's hard to run a high technology effort in Brazil," one INPE scientist says. Training technicians, potential users of Landsat data and even their own remote sensing scientists, has been and continues to be a major effort at INPE. Security restrictions imposed by the military until the beginning of 1976 required that the data be regarded as classified and released to potential users only after approval of the applicants and their purpose in seeking the data. Users in other countries (except NASA scientists) were prohibited access to Brazilian data. Even for Brazilian users the prices INPE charged were so high as to discourage wide use.

NASA officials were unhappy with the restrictions placed on access to Landsat data, since they run counter to the agency's stated policy. When the U.S.-Brazilian Landsat agreement came up for renewal in 1975, the agency imposed the condition that information for all of South America be made available to all comers at low prices comparable to those charged by the EROS data center in Sioux Falls, South Dakota. This request was backed up by the possibility of cutting off Brazil's access to the satellite altogether. After considerable internal debate and, eventually, the direct intervention of President Geisel, Brazil agreed to the new arrangements in May 1976. INPE was also given an additional $1 million by its parent agency, the Brazilian National Research Council, to upgrade the operational system and put it in better working order. Research efforts to make better use of the Landsat data, including image enhancement techniques and automatic digital processing of the data, have also been stepped up. The new director of INPE, Nelson de Jesus Parada, says that orders for data are now filled within 20 days of their receipt and that the station is operating reliably. Orders from other countries, Bolivia in particular, are growing rapidly.

Most Brazilian users of Landsat data rely on visual interpretation of photographs produced from each of the four spectral bands in which the satellite's sensors operate. The data are initially recorded in digital form, however, and thus lend themselves to image enhancement techniques and to computerized analysis. The research effort at INPE is moving in this direction. About 50 researchers are developing methods for producing soil maps, making crop forecasts, and exploiting other sources of remote sensing data. The intent, according to Parada, is to perfect methods and pass them on to others; the agency is doing some routine data interpretation now for groups of users that are not yet capable of doing their own. The researchers have at their disposal a budget of about $250,000 per year and a sophisticated computerized facility for digital image analysis bought from General Electric; the system, one of a dozen or so in the world, comes with computer programs that make it easy to enhance the contrast of a

particular image, to assign false colors, to classify portions of the image according to spectral characteristics--all in an interactive manner that allows the researcher to try one approach after another.

An agronomy group, for example, is concentrating on soil maps and is estimating crop yields in trial plots on an experimental basis. Crop forecasting would be a major contribution to Brazil, which does not have any alternative system for collecting agricultural data. This lack was pointed up by the frost that hit coffee-growing areas on 16 July 1975, and led to newspaper reports that 80 percent of the trees had been destroyed and to a strong reaction in the coffee markets; in fact, an INPE map based on a Landsat photo taken after the frost showed the damage was even more extensive, approaching 100 percent in the region studies. INPE investigators are pleased with their preliminary results in crop forecasting and hope to extend their experiments to an entire state in the near future.

The geological group is mapping four 100,000-square-kilometer regions in great detail as a way of feeling out the potential of the technique. In the process they have found a number of previously unknown structures and in one region are proposing a major revision in the accepted tectonic interpretation. Working with known areas of bauxite, iron, and tin mineralization, they are working out the identifying radiometric signatures of the ore bodies in preparation for automatic analysis of larger areas of the country that may also yield ore deposits. One study has focused on peculiar circular volcanic structures as large as 30 kilometers across. Some of these structures are known to contain uranium and thorium deposits. The INPE investigators have been able to show that most of the known deposits occur around the edges of smaller, circular formations within the larger structures, and they suggest that the pattern may be a useful guide to further exploration.

An oceanography remote sensing group at INPE is mapping coastal navigational hazards with Landsat. They are also combining Landsat images from the U.S. NOAA-IV satellite's infrared sensors in an attempt to provide daily charts of upwelling areas off Brazil's coast that are prime fishing areas. Because of a complex pattern of currents, the upwelling areas are small and tend to shift location rapidly, to the distress of Brazil's fishermen.

Very few of the results of the Brazilian Landsat effort have been published in the international literature. The major users of the data, such as the national oil company, Petrobras, or the principal mining agency, are secretive about what they are doing. But there are several indications that Landsat data are already having a substantial impact on Brazil. The national geographic institute is revising the official map of the country with Landsat data, an important task that will have more impact than it would in the United States, where accurate maps already exist.

Even more important, however, may be the uses of Landsat as a monitoring tool. The government agency charged with overseeing development of Brazil's huge Amazon wilderness, known by its initials SUDAM, is now using Landsat data to make a yearly check on the extent of deforestation in a region where many private landholders are clearing land for cattle ranches. Brazilian law restricts clearing to 50 percent of the area in a fazenda, as they are known, but in the past there was simply no effective way of enforcing the limit--a circumstance that many landowners were suspected of taking advantage of. But the Landsat photos show cleared areas unambiguously and SUDAM last year used them to resolve a number of alleged abuses.

With Landsat data now widely available for most of South America, with active programs in most of the countries, and with a second Landsat ground station in the planning stage in Argentina, remote sensing is well on the way to becoming a major development tool in this part of the world.

Project Radam--Radar Mapping

Five years ago, the Amazon Basin was a largely unknown wilderness--the largest in the world, covering 5 million square kilometers and nearly 60 percent of Brazil. Today it is still a wilderness, although the Brazilian government is stepping up its development efforts, but it is no longer unknown. The agent of this transformation is an unprecedented exploration effort known as Project Radam (for Radar Amazon). Radam has combined a sophisticated remote sensing technique with systematic investigation on the ground to produce a staggering amount of information, including the first accurate maps for much of this huge area, geological and mineral surveys, soil and timber analyses, and estimates of agricultural potential. Perhaps most striking, Radam scientists have proposed regional land use patterns for the Amazon Basin designed to protect ecologically fragile or unique regions, and to permit the planning of future development in a more rational way than has previously been possible.

Radam's productivity is based on a unique coupling of U. S. technology and Brazilian ingenuity and industry in its use. The technology is an airborne radar mapping scheme developed in the United States but first applied on a large scale in Brazil. Radar mapping is rapid and relatively inexpensive, partly because it is not dependent on weather conditions or restricted to daytime use; a single aircraft guided by a network of navigational radio transmitters can cover as much as 500,000 square kilometers a day. The technique used in Radam was developed by Goodyear Aerospace and is known as "side-look" radar because the beam is directed to one side of the aircraft flight path and strikes the ground at an angle; the reflected signal, recorded on film, yields information about

the topography of the surface as well as patterns characteristic of particular soils and flora.

The ground effort involves logistical miracles by the Brazilian Air Force and no little courage on the part of the Radam investigators. Supply planes leave Belem as often as several times a day, headed for base camps at small landing strips in remote parts of the Amazon Basin. From there, helicopters ferry crews out to sites chosen to be representative of particular regions on the basis of the radar images. Men with chain saws strapped to their backs are lowered into what is often impenetrable jungle to cut a landing pad. Other crews follow, taking soil and rock samples, studying the local biota, assessing the agricultural and mineral potential. Still others push up small tributaries in canoes or river boats to gather similar information. In the course of 5 years, hundreds of base camps have been occupied and abandoned; more than 3000 sites have been explored by helicopter, and many more by river boat. The crews risk snakebite, disease, and sometimes hostile Indians; 45 people have died in plane crashes, boat accidents, and from disease. But few have quit. Apparently the lure of the unknown, of what one Radam scientist calls "the adventure of knowing you are the first person to set foot on this place," is strong.

The information gleaned from these forays and from laboratory analyses of the returned samples is brought to Radam's cramped headquarters in Belem for interpretation and synthesis. The early results so impressed the Brazilian government that what was initially a small experimental mapping effort was expanded to include the entire Amazon Basin and, in 1976, was expanded again to include the rest of Brazil as well. Other government agencies have become regular customers for Radam's output, as have hundreds of mineral companies and private investors eyeing land purchases. The Radam results have also shown the ineptitude of some earlier development projects in the Amazon region. Roads planned over routes that turned out to be largely under water 6 months of the year have not been uncommon, nor have land-clearing projects for agriculture in regions that turned out to have unstable or practically non-existent soils.

So poorly known were some parts of the region that Radam discovered a major new tributary of the Amazon, a river hundreds of kilometers long. Mountain ranges indicated on old maps turned out to be far from their supposed locations, and a region marked out as a national forest reserve turned out to be an open savannah. Earlier soil and vegetation maps tended to suggest that the Amazon Basin is covered by a relatively homogeneous rain forest, but Radam data show that the forest is by no means homogeneous and that the soils beneath it are diverse, ranging from sand or laterite (iron-bearing) soils to rich topsoils a meter or more in depth. The geology is equally diverse--as much as 1 million square kilometers of the underlying formations appear to be volcanic, a fact that is forcing reevaluation of ideas about the early history of the South American landmass. Of great economic importance to Brazil, Radam has discovered

or greatly extended earlier discoveries of bauxite, iron ore, tin, rare earths, and other minerals.

The information gathered by Radam is made available in a series of maps accompanied by a thick book of supporting data for each section of the country--18 volumes in all for the whole Amazon Basin. In addition to the radar images themselves, six interpretive maps are published: geology, geomorphology, soils, vegetation, agricultural potential, and proposed land use categories, all on the same (radar-based) grid at a scale of 1 to 1 million. Otto Bittencourt Netto, technical director of Radam, says "these maps give us for the first time a feeling for the regional patterns" of this immense area. These patterns include, for example, variations in the type of forest cover with soil types and local climate. Not all of the Amazon is covered with dense rain forest; natural grasslands or savannahs occur. Only three regions of the Amazon Basin have year-round rainfall; other areas experience dry seasons 2 to 5 months in length. Radam botanists have identified more than 400 species of trees, and estimate the value of the standing crop of the species with known uses to be in excess of $1 trillion. (Exploitation of hardwood species in a big way is not now contemplated, however, because the trees would sink in water and are so huge, often 60 meters high, that anything other than river transport would be difficult.)

Soil patterns are equally surprising. Although much of the soil is poor in nutrients, pockets of good soil exist. Radam scientists found one large area in the westernmost reaches of the Amazon that contains 100,000 square kilometers of thick, fertile soil capable, they say, of supporting intensive agriculture. Netto estimates that at least 2 percent of the Amazon Basin consists of good soil, and he points out that the radar images recently led to the discovery of large deposits of limestone which, if added to neutralize the acidic soils of many plateau areas, could make them productive as well. In large areas, however, the soils will not support use at all, turning to sand or (in laterite areas) to rock when the covering vegetation is cleared.

The land use category map is, in a sense, the summation of the information on the other six maps, but includes as well the results of sociological surveys of any existing inhabitants of the region. They were asked what crops grow well, what institutions and infrastructure (landing strips, schools, and so on) already exist in the region, and the state of the local economy. The map attempts to single out the most promising areas and activities for development, points out restrictions posed by soil or vegetation, and proposes regions for preservation. Specifically considered are any known mineral indications and the potential for lumbering, raising cattle, and agriculture.

A typical example is a 290,000 square kilometer region in the south-central Amazon Basin, on the boundary between the states of Amazonas

and Para. The Rio Tapajos runs through the region, which is heavily forested. The Radam maps indicate that lumbering is, in fact, nearly the only activity that ought to be contemplated, although there are some indications of gold, tin, and several other minerals scattered throughout the region. The soils are too poor to support intensive agriculture, and the existing vegetation is not appropriate for cattle ranching. In a few places, however, especially along river beds, there appears to be a substantial potential for cultivation of extractive products such as palm oil. A number of areas are marked as unexploitable by law, because the slopes are at angles greater than 45°, or as needing special protection because of their fragility.

All these maps, with the exception of the radar images, are made essentially by hand. That is particularly remarkable because the scientific staff of Radam totals about 150, and these same people perform the fieldwork. The operation has been a lean one in other ways as well. The total cost of the effort has been about $40 million for the first 5 years. Radam has also had what seems to be a remarkable degree of autonomy in developing its own sampling and interpretive techniques and deciding what information should be published, and in what form.

Radam is highly regarded in Brazil, as well it might be. More to the point, the information it is providing is being actively sought and used by government planners. Even the proposed land use designations seem not to have become controversial, and there are indications that they are being adopted by other agencies. Radam has provided the means for what one Brazilian describes as "a rare opportunity--the chance to plan a continent's development before it happens."

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The Uses of Remote Sensing

Vikram Sarabhai and Colleagues

[Remote sensing is useful in a variety of practical applications. In addition to more familiar uses for mapping of land areas, there are a number of specialized uses in understanding the role and resources of the oceans, and in mineral exploration as well as water resource planning.]

Remote sensing is the acquisition of information about specific objects or phenomena by an information-gathering device at some distance from the subject under investigation. Remote sensing techniques have applications in the following disciplines: agriculture, forestry, oceanography, geology, hydrology, geography, and pollution control.

Agriculture and Forestry. Repetitive aerial surveys during the vegetative growth and harvest times of a crop can provide reliable inventories of the size of the harvest, as has been shown on a limited scale. Remote sensing from orbiting satellites promises to extend such predictive techniques to very large areas with many crops such as rice, wheat, maize etc.

Use of multispectral imagery [see next article for technical explanations] is expected to be of great help in the identification of crops and timber species, in the analysis of crop vigor, in the early detection of crop diseases and other forms of crop stress--for example, that are due to deficient water supply. The evaluation of the large-scale effects of different kinds of fertili-

Dr. Sarabhai was Chairman of the Indian Space Research Organization which was asked to prepare this report for the UN Advisory Committee on the Application of Science and Technology for Development.

zation and irrigation practices on agricultural land can be carried out more satisfactorily through remote sensing techniques than through isolated conventional ground measurements at a few selected spots. Rapid inventories of livestock at night can be made with remote infra-red sensors. The utility of repetitive observations of large agricultural areas over a short period of the order of one month cannot be over-emphasized. Remote sensing is perhaps the only technique capable of achieving this with any degree of reliability.

The Food and Agriculture Organization of the United Nations (FAO) has made use of remote sensing techniques with aircraft platforms in the preparation of world soil maps, world forest inventory, desert locust control, etc. FAO, for example has taken steps to undertake collaborative programmes with NASA for obtaining pictures from satellites over selected areas of the Sudan, Colombia and the Philippines, where FAO already has some projects in operation.

The following table summarizes the major applications of remote sensing to agriculture/forestry, using both infra-red color photography and multispectral images, with repetitive acquisition.

Crops:	crop census, crop vigor, crop yield estimates, marketing data, insect and disease detection and their forecasting.
Animal Husbandry:	livestock census, rangeland biomass conditions.
Land and Water:	land use inventories, soil surveys, drainage, mineral deficiency, irrigation management, estimation of saline, waterlogged and eroded areas.
Forestry:	forest resources inventory and management, tree growth rate, forest fires, forest tree diseases.

Oceanography. More than 70 percent of the earth is covered by the oceans. Unlike the static ground surface, the ocean surfaces are subject to continuous change. Their expanse, coupled with their dynamic nature, makes a broad-scale surveillance by conventional methods of ship-borne instrumentation practically impossible. Even if a large number of ships were employed their best efforts would be limited to selected data points. There are many ocean locations which have not been visited by man, even areas of special interest have only occasionally been looked at from ships, and, nowadays, from aircraft.

Our earth being a spacecraft without any external supplies, all the fresh water used by man and animals has to be recycled. This is effected

through evaporation and subsequent precipitation. The evaporation from the oceans is the ultimate cause of all clouds and precipitation even over land areas. The role played by the location of abnormally warm oceanic areas in causing the vagaries of the rainfall is gradually being realized by meteorologists. Thus, a survey of the oceans becomes essential for the forecasting of weather over land and sea.

The Gemini manned spacecraft missions in the 1960's obtained color photographs of the earth's surface during their flights, taken for the first time outside the earth's atmosphere. Taken only with hand-held cameras, these pictures revealed the potential of surveys of the earth and its resources made by remote sensing from space. They were remarkably clear, clearer than those taken from aircraft, due to the fact that the camera's lens was many miles away from the atmospheric scattering medium. These pictures covered thousands of square miles at one time, showing large patterns and formations which cannot be seen in aerial photographs. A vertical view of some coastal areas in Florida, for example, showed shallow areas and underwater detail through color tones. Sedimentation patterns over large lakes were clearly discernible. Several atolls 60 miles or less in diameter appeared in the central Pacific.

Plankton and fish are perhaps the most important oceanic resources. In the years ahead, these resources must be surveyed, monitored, conserved and wisely harvested. There is a significant correlation between ocean temperature and the location of large schools of fish, so that information on the ocean temperature gathered through infra-red heat sensing would prove valuable to the fishing industry. Surface temperature measurements also help to identify the locations of highest plankton concentrations and therefore possible locations of large populations of fish.

The oceans absorb surplus carbon dioxide in the atmosphere via phytoplankton which convert it into oxygen. Some scientists feel that the overload of industrially emitted carbon-dioxide might have already saturated the ocean's capacity to effect this conversion. This also makes it necessary to monitor the areas of phytoplankton. Phytoplankton can be killed or their vigor impaired through oil slicks or pollution films. With so many oil tankers, the risk of such films is large over the Arabian Sea, and with many countries drilling for oil under the water the risk of oil slicks spreading over the oceans is increasing. It is desirable to monitor them. A satellite sensor scanning in the near ultra-violet and thermal infra-red can detect oil slicks, both those which are only a few hours old and those which are several days old. It is not known definitely whether schools of fish create detectable thin films of fish oil. If so, the same technique of ultra-violet sensing might detect schools of fish just below the surface.

Subtle gradations in ocean color in the Gemini photographs correlated well with ocean flora. Hence this technique can be used to indicate

areas of high food content where fish are more likely to be found. Ocean color gradations in shallow waters can be used to update hydrographic charts, which is very necessary as the action of tides and currents is continuously changing the contours of the sea bottom, faster than the classical hydrographic surveys can measure the changes. From a space platform, small differences in color can be detected through the use of multispectral photography or scanning imagery, using narrow band filters.

The areas and intensities of the "sunglint"--the area of an ocean surface which reflects sunlight into the observing camera--provide data on the surface waves, which can be related to the surface wind. The state of the sea also produces differences in the sea color when viewed vertically. Remote sensing techniques for these features installed in spacecraft can provide information on the state of the sea. The state of the sea can be inferred more definitely by the use of microwave radiations. The information about the state of the sea can be used for appropriate rerouting of ships along routes which offer less resistance to the ship's motion.

SOME APPLICATIONS OF SPACE TECHNOLOGY TO OCEANOGRAPHY

Application	*Type of data*	*Inferences drawn from the data*
Shipping	Wave height	State of the sea
	Surface temperature Surface temperature gradients	Currents
	Water colour Temperature anomalies	Hazards such as icebergs
	Water/ice interface	
Meteorology	Wave heights	
	Water colour	Winds
	Surface temperature	Evaporation
	Temperature anomalies	Cyclone development
Coastal geography.	Land/water interface	Shore line topography
	Colour tones and contrast Water colour tone	Effluents from rivers and sediment deposits
	Water surface elevation	Sea level and slopes
Marine biology ...	Colour tones	Bioluminescence
	Colour tones	Plankton
	Colour tones	Schools of fish and algae
Sea food	Sea surface temperature gradient	Upwelling
	Water temperature gradient water colour	Current and eddies
	Wave refraction and colour tones	Bottom topography
	Ultra-violet or other vapour features	Oil slicks of petroleum origin or of fish origin

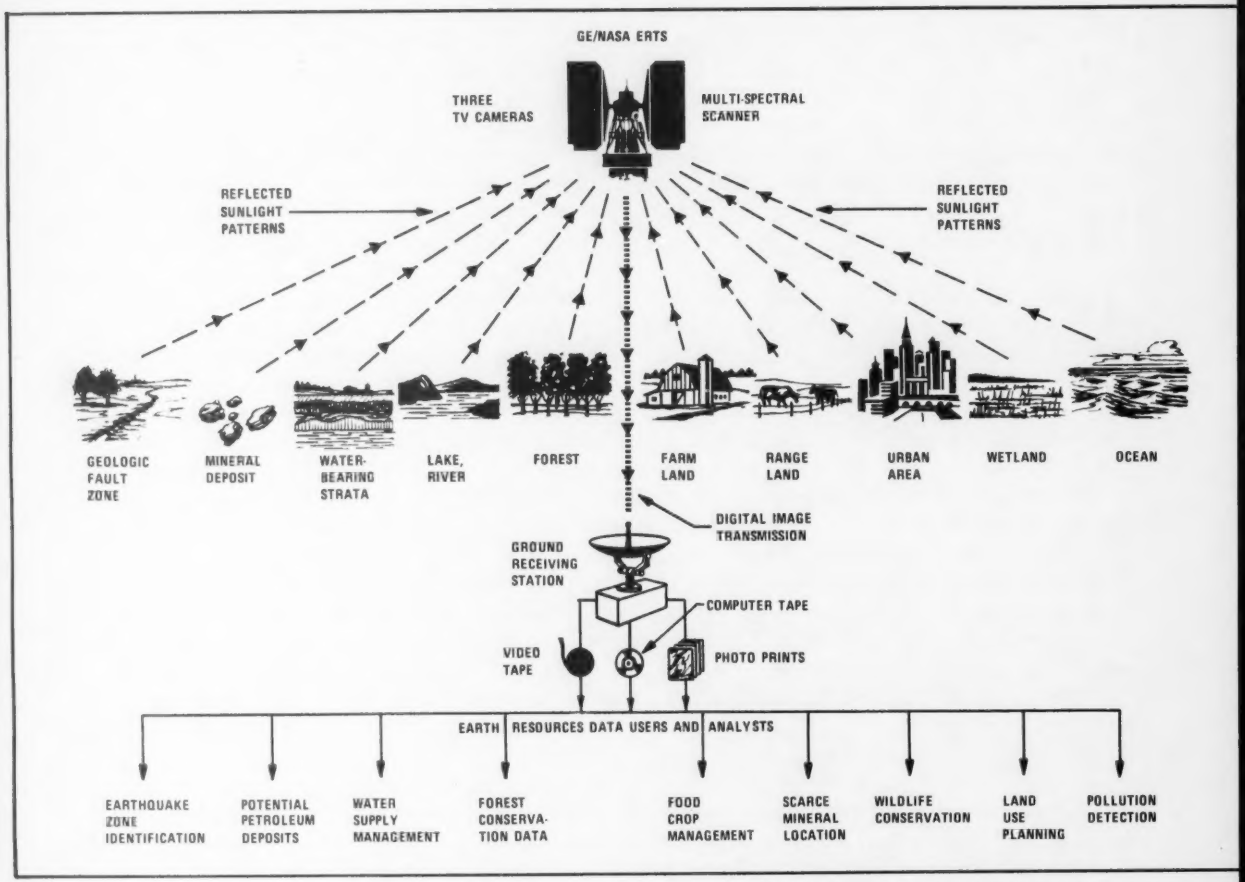
Hydrology. Fresh water is an extremely important terrestrial resource which requires proper management. The basic principle in water

management and utilization is to intercept the water when it is still fresh and to utilize it for human benefit before it returns to the atmosphere as water vapor or to the ocean as contaminated water. The atmosphere contains about 10 millionths of the total water; all fresh water returns to the earth after staying in the atmosphere for a brief period, on the average of 12 days. In other words, the atmospheric water vapor is replaced about 30 times a year. However, its passage to and its precipitation on the land are extremely variable in amount and distribution.

Hydrological data have been collected through rain-gauge stations, snow-gauge stations, stream-gauging stations, snow-depth stations, water quality stations and ground-water observation wells, evaporimeter stations, etc. Such a collection of data demands considerable time, funds and technical skill. Hydrology is a natural science highly dependent on current new data; perishable hydrological data have to be collected expeditiously over a wide area if the performance of water management functions is to be satisfactory. Space technology using remote sensing and communication satellites appears to provide a satisfactory solution for the data collection problem. They can provide large-scale, repetitive imagery of water systems significantly supplementing data taken at individual points. In addition, automatic sensors collecting data at individual points can transmit the measurements to a satellite, which can rapidly pass the data to a hydrological center. Such an operational system has a feasibility for providing global, synoptic, repetitive real time coverage of the major aspects of the hydrological cycle.

A few examples of what can be done with such a system are the following: The available water in an entire river basin or lake system can be monitored repetitively. Repeated observations in the visual, infra-red, and microwave regions of the spectrum can be made of snow, glaciers, ice accumulations and melting patterns. These changes can be monitored during the seasons of the year over areas too large to survey by conventional means. More accurate predictions of the run-off can be made. These forecasts, in turn, will enable hydrologists to issue better flood warnings and to regulate efficiently impounding and release of water in reservoirs. Programs of flood control, irrigation, and power production, as well as water for urban and industrial consumption can be wisely carried out.

In addition to reporting water inventories, remote sensing may help to reduce underground fresh water being lost to the sea. Aerial infra-red detectors flown over the coast of Hawaii, for example, showed nearly 250 underground springs discharging cool fresh ground water into the comparatively warm ocean. Such pictures may guide water prospectors to likely drilling points. The same thermal principle can be used to locate areas where cool underground brackish water intrudes into the warmer rivers. The location of such zones can help in the protection of municipal water supplies which rely on rivers.



How satellite images serve development planning: Typical ground features recorded, and planners' uses of the information

Geography and Cartography. Any plan for national development requires current, accurate maps. Geographers are concerned with the location, arrangement and association of the earth features, such as rivers, mountains ranges and sea coasts, and of man-made features, such as roads, towns and artificial lakes. Maps form the framework on which these features are marked. Maps also define the location of the various mineral resources. Normally, such maps are prepared through ground triangulation surveys involving considerable time and effort, and therefore also funds. Cartographers are continuously engaged in resurveying and preparing maps, and yet 70 percent of all the small-scale maps of the world are out of date, and the remainder are inadequate.

The best current method of obtaining accurate small-scale maps of large areas appears to be aerial photography. The compilation of small-

scale maps is a slow laborious process, even when aerial photography is employed. At least half a million such photographs would be required to make a satisfactory photo-mosaic of a country the size of India. Preparing such a mosaic is time-consuming and costly. From a satellite altitude, such a panorama of India would require no more than 200 pictures which could be assembled in a few weeks. In just one pass, the Gemini astronauts photographed almost 80 percent of Peru in a total time of only three minutes. In the mosaic thus obtained could be seen the gross patterns of land use, distribution of snow, the levels of the lakes and geological forms of significance--in fact more information than any available map of the region could offer.

New maps made by satellite effectively supplement existing specialized maps and together will be of great value to all of the geographical disciplines. Demographers will have new, updated imagery to use in assessing changing patterns of population and migration. Land use planners can see the actual patterns of land use all across the country. They can also see seasonal changes in these patterns. Urban geographers and city planners will have a continuous record of changing urban patterns. Regional planners, transportation planners and cultural geographers will also strengthen their analyses with new information.

Geology and Mineral Resources. Mineral resource surveys aim at understanding the geologic environment of mineral deposits and how they are formed, in order to make an informed estimate of where they might occur. One of the geologist's chief information tools is the geological map which shows the distribution of rocks exposed at the earth's surface. In the past, the field geologist studied and mastered a small area which he supplied toward a broad, regional picture to which others contributed. Large-scale geological maps were the laborious product of years of surface exploration. Now, in addition to aerial photography, geologists can have the big, synoptic view offered by remote sensing. These systematic space pictures will offer geologists a broad, integrated panorama from which they can select observables of interest for close-up looks by aircraft or ground parties. The advantage offered by observations from space is that aircraft of prospecting surveys can be directed to specific areas of interest. Geological uses of satellite pictures are still in a somewhat experimental stage, but some aspects of these uses can be described.

Known relationships exist between concentrations of mineral and fuel resources and particular geological features. Petroleum and metallic mineral deposits, for example, are frequently found near structural features such as folds or faults. In a space photograph, part of an entire mountain range could consist of a series of folded rocks, and in the series of folds might lie an anticline or dome which could yield oil. Pictures from orbital altitudes have proved superior to those from planes for viewing the larger linear geologic features. A new fault system in

southern California was first discovered in space photographs. Geologic fractures and faults are even more obvious in radar images than in visual pictures; radar also penetrates clouds and haze, and can be used during night-time.

Satellite observations may be useful to geologists in other ways. Some mineral deposits yield heat through oxidation and may be detected by thermal infra-red sensors. Repetitive satellite observations of the melting patterns of snow may also point to such deposits. Thermal infra-red imaging also indicates temperature differences at or near the earth's surface. These differences may indicate possible sources of geothermal power and volcanic activity. Repetitive observations in the visible and thermal infra-red regions may disclose crustal movements and thermal gradients which could provide timely data for predicting natural disasters such as earthquakes, volcanic eruptions and landslides. The following summarizes applications of remote sensing in geology.

Application	*Type of data collected*	*Use of data that obtained*
Detection of petroleum and other minerals...	Coloured, black-and-white and infra-red photographs	Rock information
		Earth folds
	Magnetic field strengths	Drainage patterns
	Electrical conductivity values	Outcrops
		Location of magnetized ores
		Location of conducting minerals
Prediction of volcanic action ..	Thermal infra-red data	Anomalies of surface temperature
	Colour photographs	Rock identification
		Spatial patterns
Prediction of earthquakes	Thermal infra-red data	Linear microtemperature anomalies
		Time variation of slopes

[Extracted from Chapter 4 of The Application of Space Technology to Development, pp. 38-49. New York: United Nations, 1973. UN Sales Number E72. II. A 12.]

Techniques Used in Remote Sensing

Charles Dorigan

[This article attempts to explain for readers who are not scientists the technological components of the systems used in remote sensing. It describes some of the theory and the mechanics of how the images are recorded, analyzed, and interpreted.]

Remote sensing systems used for surveys in developing countries employ aerial photography and a variety of methods for obtaining observations from earth satellites, such as Landsat and weather satellites, as well as radar, thermal sensing, and many other technologies. Up to now, most projects for use of remote sensing in resource analysis have been conducted by a relatively limited number of scientists and planners, most of whom have had a prior interest in and basic understanding of the technology. As its uses in resource development programs increase in scope, complexity, and geographic area, many more planners and policy makers as well as scientists need to realize the potential of this exciting and productive technology so that it may be used more effectively. This article describes the salient features of the two most widely used remote sensing systems, Landsat satellites, and aerial photography. It provides a brief account of some of the technical aspects in order to assist the non-specialist in understanding their contributions to resource surveys and analysis.

A survey of the physical resources of a country, or a region within a country, involves assessment of the possibilities for uses of land in agriculture, livestock, forestry, or other purposes, as well as estimates of

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possible sources of water, and of various minerals. Such assessments require the coordinated activities of a group of scientists from different disciplines, as well as economic planners and others who will have to deal with policy makers. Land use, for example, involves the knowledge of a variety of soils and their potentials for cultivation, and the environmental results of cultivation intensities; and knowledge of a range of plants that might be grown, the requirements of animals that might be pastured, as well as the qualities of trees that might be grown for forestry uses. Mineral exploration involves geologists; fisheries development and ocean current analysis involve marine experts. All these different specialists, including those concerned with the requirements for financial resources, must work together to determine what are the most practical uses of a given area. They must therefore comprehend the nature of the findings obtainable from remote sensing and ground studies on which they will rely for their basic information. This kind of work is being done at a growing rate today, not only in countries with an established core of scientists but--even more significantly--in areas that have been inadequately surveyed such as Mali or Upper Volta, Bolivia or Nicaragua, Aden or Nepal, where the new technologies are generally unfamiliar.

Photographic and Scanning Systems

Remote sensing equipment ranges from simple cameras to very sophisticated systems of data collection and handling. Here we will concentrate on two types: photographic cameras, and electronic scanner systems. They are illustrated in Figure 1.

In the remote sensing vernacular, photographic systems imply the use of a camera to focus light energy directly onto a film. In general, camera systems provide better "resolution" than scanner systems, given similar operating conditions. That is, photographs supply a more clear and finely detailed picture of what they show. Photographic systems also portray the environment in a more recognizable manner to most individuals; and when overlapping photos are taken they can be presented stereoscopically--i. e., showing three dimensions--to aid in interpretation. Aerial photography remains the most used of remote sensing systems.

Non-photographic "imaging" systems include various kinds of scanners, from which the final visible product does not result directly from light being focused from a lens to a film. It is instead a result of light rays (and others) reflected from earth to a device called a sensor; they are received by the sensor in an airplane or satellite and then converted to electronic signals. These can then be transformed into a photographic-like product by the same method that electrical impulses are transformed into the image on a television screen. The Landsat satellite carries a scanner system: a sensor scans (that is, sweeps rapidly over) the area that is to be observed, and picks up electromagnetic impulses from the earth (described in more detail later). In one such sweep, the scanner will take in a horizontal line of thousands of instantaneously resolved units of

reflected energy; when these are translated into images, they are called "pixels" (i. e., "picture elements"); the next sweep takes in an adjacent line of pixels, and so on; sufficient lines can be accumulated to form a complete image. A single square Landsat image, for example, is composed of 7.6 million pixels. The pixel is, in effect, a dot, or point, the smallest unit in an electronically produced image.

The scanner, unlike the camera, provides an electrical output (i. e., the rapid stream of impulses which are to become pixels) that can be immediately broadcast to an earth station. There it can be processed for simultaneous viewing, or it can be recorded on tape in the earth station for storage. (Photographic films must be brought down to earth and developed for use.) Another advantage of the products from a scanner is that they can be adapted to computerized processing techniques. The elements which form the pixels are stored on tape in the form of bits of electrical energy. Measuring the amounts of reflected or transmitted energy in each pixel adds a quantitative capability to the analysis. Because each pixel is a separate and measurable entity, groupings of pixels can be modified by computer processing in order to obtain other products. This is one of the most important properties of scanner-acquired data, since great advantage can be taken of the information when it is computer-compatible.

Another important capability of the scanner sensors, as opposed to cameras, is that they can sense a wider range of wave impulses. The waves that the eye can observe as light rays of different colors are one portion of a wider spectrum of electromagnetic impulses, originating with the sun and reflected back from various observable objects on earth; these impulses are distinguished by variations in wavelength. In the visible color part of the spectrum, violet is the highest frequency wave, followed by blue, green, yellow and red--which is the lowest frequency visible. Infrared means "beyond the red" and occupies a portion of the electromagnetic spectrum ranging from the visible down to the micro-wave frequencies. Just beyond the red wavelengths, humans lose the capability to perceive reflected energy with the naked eye. There is a transition into the reflected infrared spectrum. (This portion of the spectrum has nothing to do with heat, which is found at a different portion of the infrared). The electromagnetic energy at these wavelengths is great enough to produce an image on a specialized photographic film, and is sometimes called "photographic infrared". Such film is noted for revealing healthy vegetation (which reflects strongly in the infrared) in red color, while diseased or stressed plants appear in yellowish to bluish tones. Since this kind of film causes objects to appear in different colors than those seen by the human eye, it is called "false color" infrared film. In addition to vegetation analysis, this film is valuable for detecting moist soils, waterbodies, etc., which appear dark or black on the photographs, since the moisture absorbs the infrared wavelengths.

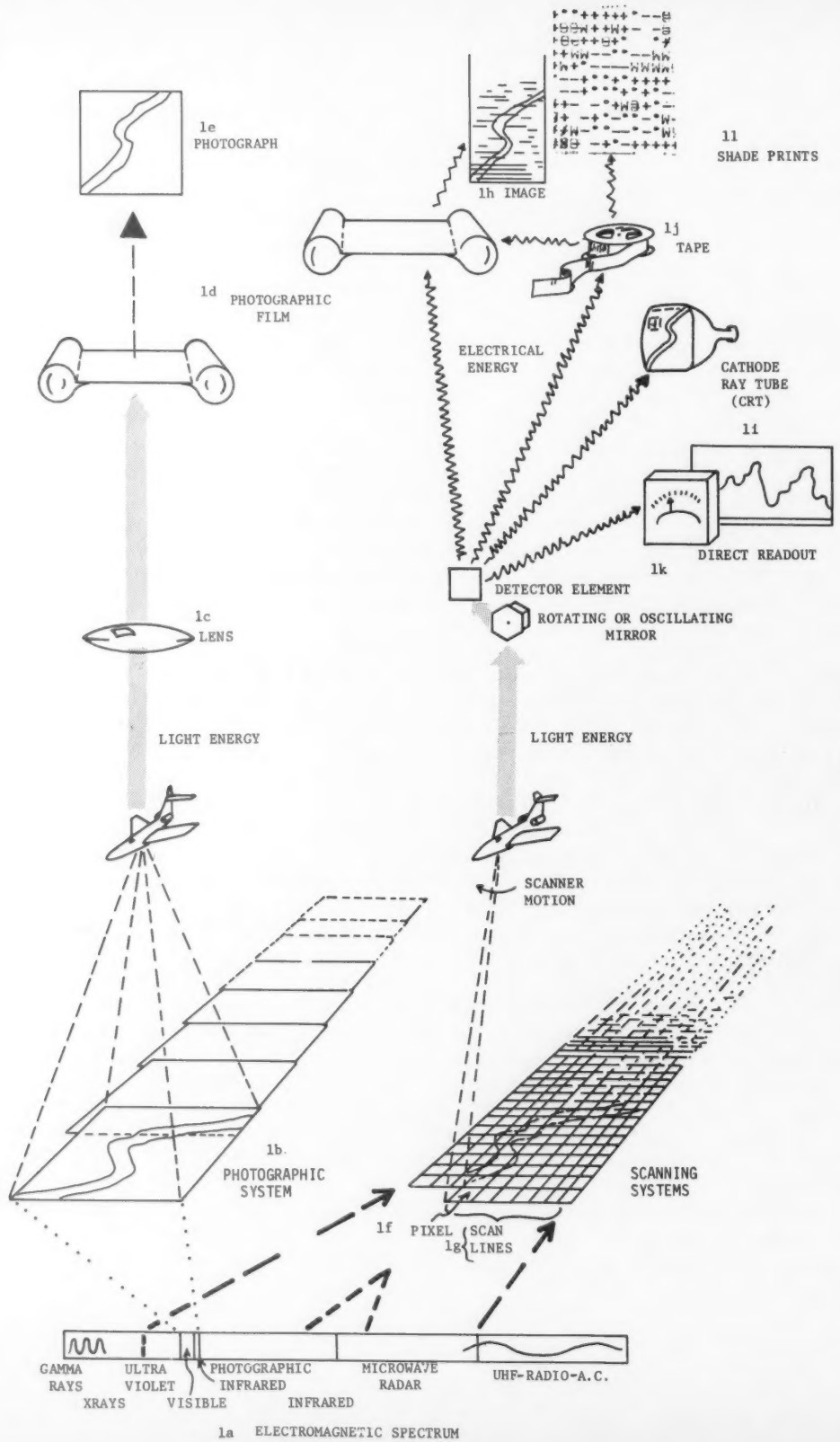

FIGURE 1: Photographic and Scanning Systems

As we move deeper into the infrared region toward longer wavelengths and lower energy, the capability to expose film emulsion is lost and there is need for a different kind of sensor that will translate the appropriate type of energy into an electrical signal which can eventually be displayed in several modes including a photographic-like product. These detector units record heat energy emitted by objects on the earth's surface or by the earth. The use of such detectors is called thermal sensing or thermography, and has a number of important applications. Some examples of thermal sensing uses are geothermal energy exploration, and temperature analysis of soils and ocean surfaces for a variety of purposes.

The next step into lower frequencies beyond infrared is to the microwaves. In remote sensing, these frequencies are employed for radar, and for microwave radiometry. Radar systems are based on sending out electrical impulses and then receiving those which are reflected back. The intensity of the return signals depend on the angles with which the radar impulse contacts objects, and they can indicate the size, shape, texture and structure of objects. Radar was developed in World War II for detecting airplanes and ships and to measure their distance; today, many sensitive and sophisticated radars can be used for resource analysis. Since radar with its longer wavelengths passes through clouds and rain, and is as useful at night as in daylight, and because it can be made to reflect certain kinds of geological differences in the surface of the earth, radar is a valuable addition to light wave and infrared sensing.

(To complete an account of the electromagnetic wave spectrum: the next lower frequency waves beyond the microwaves are radio waves, and beyond that alternating electric current waves. At the higher frequency end of the spectrum, beyond visible light waves come the ultra-violet waves. These have certain specialized uses for remote sensing such as detection of oil spills and mineral exploration. Next higher in frequency are X-rays, whose medical uses derive from an ability to penetrate softer materials or tissues but not harder ones. At the extreme high frequencies are gamma rays such as those detected by a Geiger counter. Generally, the highest frequency waves have the shortest wavelengths and highest energy, and the lower frequencies are lower in both respects. Frequency refers to the number of waves passing a point per unit of time, and wavelength to the distance between one wave crest and the next. Electromagnetic energy moves steadily through space at the speed of light, irrespective of wavelengths. The electromagnetic spectrum is shown at the bottom of Fig. 1.)

Multi-Spectral Analysis. Several methods of refining remote sensing information for analysis are common to both photographic and scanning systems, one of the most common being multispectral analysis. This is done in both photographic and scanner systems by using filters to modify the incoming electromagnetic energy reaching the sensor so that objects imaged in these bands will be recorded only in particular ways. In photographic systems, an optical filter allows only selectively filtered wavelengths within a defined frequency range to activate emulsion on film:

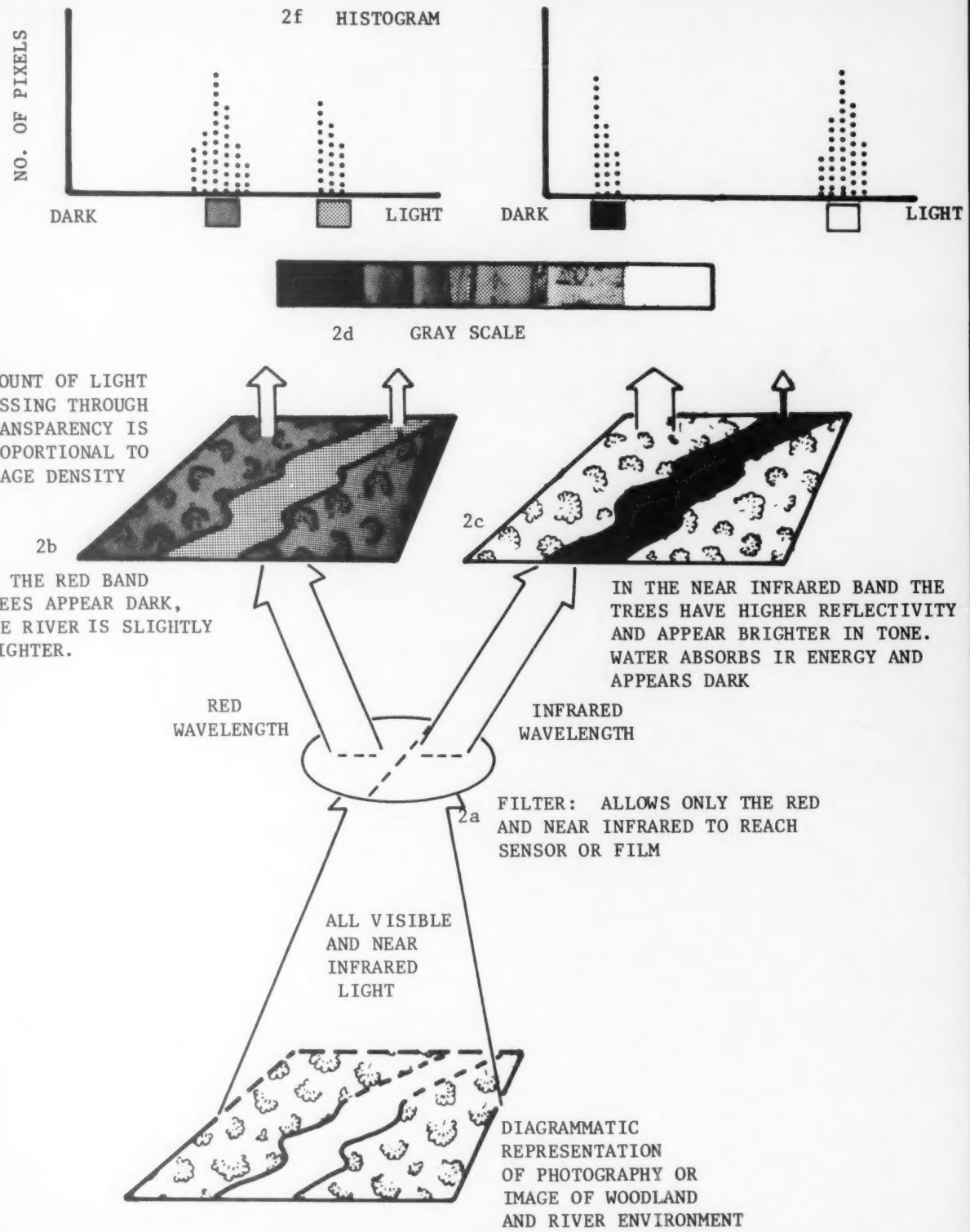
2f HISTOGRAM
NO. OF PIXELS
DARK
LIGHT
DARK
LIGHT
2d GRAY SCALE
AMOUNT OF LIGHT PASSING THROUGH TRANSPARENCY IS PROPORTIONAL TO IMAGE DENSITY
2b
IN THE RED BAND TREES APPEAR DARK, THE RIVER IS SLIGHTLY LIGHTER.
2c
IN THE NEAR INFRARED BAND THE TREES HAVE HIGHER REFLECTIVITY AND APPEAR BRIGHTER IN TONE. WATER ABSORBS IR ENERGY AND APPEARS DARK
RED WAVELENGTH
INFRARED WAVELENGTH
2a
FILTER: ALLOWS ONLY THE RED AND NEAR INFRARED TO REACH SENSOR OR FILM
ALL VISIBLE AND NEAR INFRARED LIGHT
DIAGRAMMATIC REPRESENTATION OF PHOTOGRAPHY OR IMAGE OF WOODLAND AND RIVER ENVIRONMENT

FIGURE 2: Multispectral Landsat Images

simultaneously other filters select out waves from other frequency ranges for other films (Fig. 2a). It is also possible to use a multilens camera with each lens focusing on different parts of a single film. Scanner systems can accomplish this same kind of filtration electronically. Hence, one hears the terms "band" or "channel" as in multiband cameras, or multichannel "spectral" scanners.

Each of the selective filtering devices records information within a specific portion of the electromagnetic spectrum defined in units of wavelength, and often described in terms of the nearest color represented by that wavelength, such as red band, blue band, etc. Objects imaged in these bands will have unique "tone signatures" in each band, that is, a precisely defined appearance resulting from the amounts of light energy they either absorb or reflect and return to the sensor (Fig. 2). Highly reflective objects appear bright, objects absorbing energy appear dark. (In Fig. 3, two photos of the same area but in different bands are illustrated.) Degrees of reflected intensity are referred to as "image density". Images on photos from within a single band are often produced as a series of monochromatic (black-and-white) transparencies or photographic prints. The range of tones from black to white appearing on a photograph or scanner image are arbitrarily divided into a unit of calibration called a gray scale (Fig. 2d): modern image processing techniques can produce 256 gray tones ranging from black to white. Photographs have a continuous gradient of tones, while scanner images produce gray tones in discrete units, the pixels. The gray scale value of each pixel is generally indicative of the physical properties of one part or all of some specific environmental entity, such as vetetation, soil, water, etc. In this way a new dimension of information analysis and control is achieved.

For example, a small "scene" within an image can be selected out for analysis; a computer can print a "histogram" i. e. a diagram showing the frequency distribution of gray scale values for all the pixels within that scene (see Fig. 2f). In this way the image densities of elements within a scene, as reflected in a single band, are precisely defined. Once the histogram of gray scale values reveals a specific distribution of pixels, and this distribution is equated with a particular known environment (e. g. a type of vegetation or soil), the computer can then mechanically search throughout a large imaged area for the particular qualities defined in the histogram and thereby locate the places where the same environment can be found. (This must, of course, be checked on the ground; but the search is greatly accelerated.) In order to improve visual interpretation of images, the light-dark contrasts in a scene can be enhanced, or subdued. Gray scales can be "stretched" to enhance small differences within environments that appear uniform. These are a few examples of what can be done by "digital" processing, i. e. computer processing of data which can be obtained in discrete (i. e. separate and measured) units. Scanners supply discrete pixels; but photographs or other continuous-tone products can if

desired be converted to a form having separate small units, i. e. they can be "digitized" by close-up scanning.

The separate monochromatic images from different bands covering the same area can be photographically combined and presented as a color composite image or photograph. This is done to combine the special characteristics of objects imaged in each of the non-visible bands of the spectrum in conjunction with visible ones. Most commonly the colors used are similar to those of infrared false color film, in which the areas of heavy vegetation are shown as bright red; and other objects appear in other colors such as green, yellow or blue which are not their colors as seen by the eye. These images can be very beautiful as well as highly informative to a viewer who is aware of what he is seeing, although they can also be confusing or even misleading to the viewer who is not properly informed.

Coverage of the Landsat Satellite

Most of the operational projects conducted for resource studies use either aerial photography or Landsat imagery unless a more unusual system is needed for some particular purpose. There are two Landsat satellites in orbit now: Landsat 1 was launched in the summer of 1972, and Landsat 2 has been in orbit since February of 1975. A third one (Landsat C) will be launched in early 1978, and a fourth (Landsat D) in 1980; the latter will have an infrared thermal sensor, and will have a higher resolution--that is, each pixel will cover about 900 square meters, compared to the present 4800 m^2.

Each Landsat satellite orbits the Earth once every 103 minutes at an altitude of about 915 km (570 miles). For a specified period of time each day, mainly when the satellite is over land, a four-channel multispectral scanner and a return beam vidicon (a kind of miniature television three channel system) are activated. The satellite is programmed to image a new 185 km (115 mile) wide flight line, overlapping and adjacent to the previous day's flight, on each consecutive day. Image acquisition from north to south during each daily sequence occurs at the same local time of day; this is called a sun-synchronous orbit. It requires about 45 minutes for the satellite to travel from 80° North latitude to 80° South latitude, maintaining an average 9.42 a. m. local time for each flight line. The satellite returns to the same location on the earth at the same time every 18 days. With two satellites aloft, there is a repetitive coverage of the same location every nine days (there have been some recent changes in this flight schedule). This continuing coverage is one of the most important assets of the Landsat system, since changes in the environment can be monitored through the year (except when covered by clouds).

The multispectral scanner records information in four bands: the green, red, and two near-infrared (reflective infrared bands). Very generally,

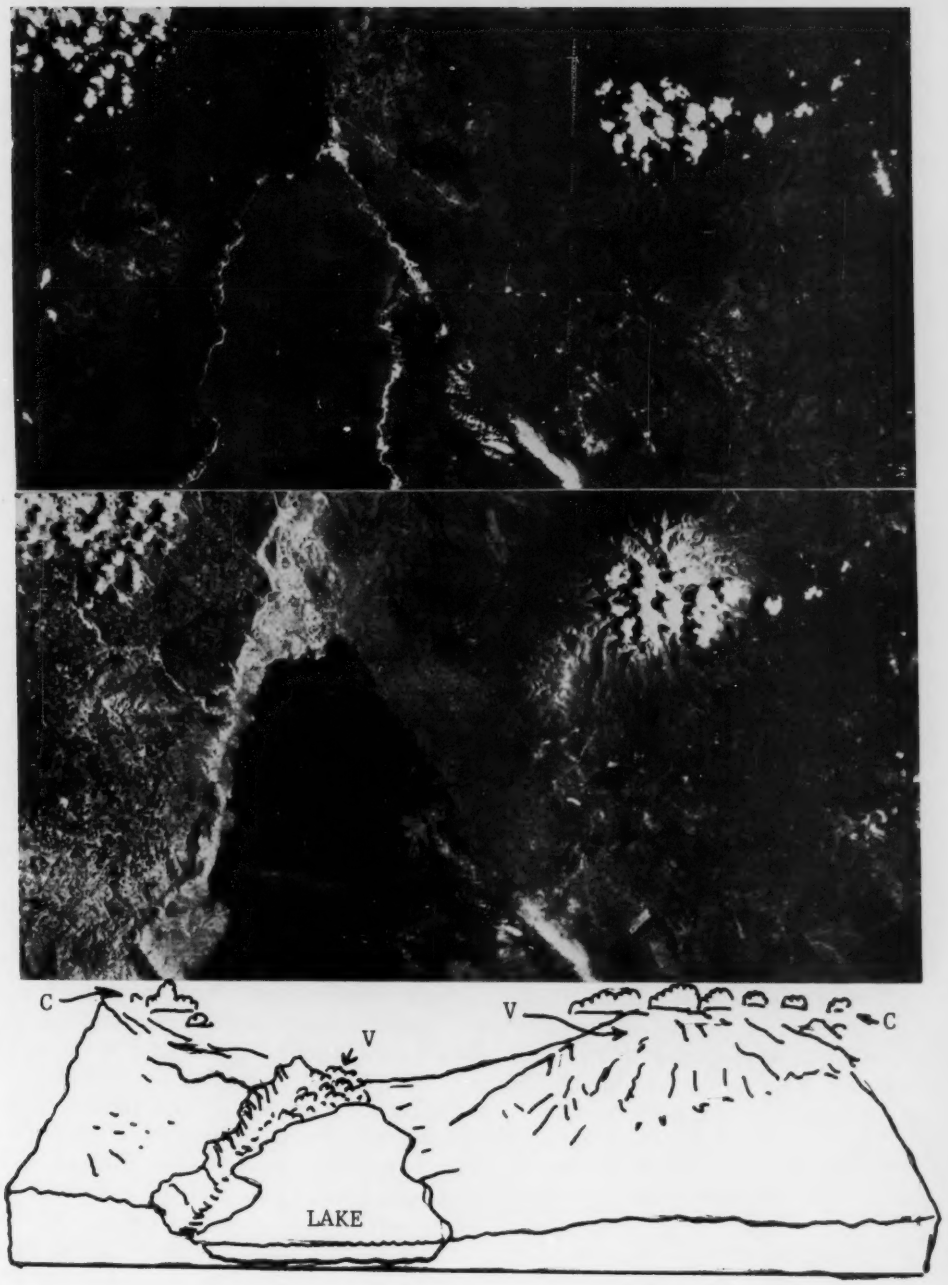

Figure 3: Multispectral Landsat images. Portions of two bands of Landsat images illustrating examples of the differences between water and vegetation in each band. The image at the top, Band 5 (red) shows vegetation dark and water somewhat lighter. The Band 7 (infrared) image shows vegetation white and the lake black. The location of the vegetation (V), the lake, and clouds (C) are indicated in the sketch below the photographs.

green (band 4) information is good for detecting cultural features like urban development, roads; vegetation appears light, water bodies do not stand out particularly well. Atmospheric interference of the green band wavelengths often results in hazy images. The red (band 5) images show healthy vegetation in dark tones and water very dark, unless it is sediment laden. Geologists find it good for interpreting rock structure. The near infrared bands (6 and 7) image healthy vegetation as very bright, and allow increased discrimination capability between vegetation types. Water bodies appear dark or black, moist areas are accentuated. The minimum resolution element of a Landsat image is a pixel of approximately 59 x 79 meters or 0.45 hectare (1.1 acres). Each Landsat image is composed of approximately 7.6 million of these pixels; and each image covers 34,225 square kilometers (185 x 185 km). By using the modern computer processing techniques described earlier, these images can be modified to enhance scene information, or corrected for distortions in image geography caused by satellite movement and the rotation of the earth.

The Landsat imagery is stored, and made available at relatively modest cost, at the EROS Data Center, Sioux Falls, South Dakota, U.S.A. in what is known as bulk processing form, that is, as initially procured from the tapes with some standard methods of images corrective applications. Computer-compatible tapes can also be obtained from EROS. Normal delivery time is several weeks. Specially processed imagery is obtainable from several private firms at higher cost. Similar products can be obtained from: Instituto de Pesquisos Espacies (INPE), in Sao Paulo, Brazil; and from Telespazio Corso d'Italia, Rome, Italy.

In addition to the Landsat satellites, weather satellites carry an array of instruments allowing scientists to monitor atmospheric, cloud, terrain, and water temperatures, cloud cover, rainfall events, and other weather phenomena. From these data, estimates of soil moisture potential, evapotranspiration, rainfall amounts and other information important in resource analysis is gained. Much of the imagery and data can be received and broadcast by ground stations in "real time" (that is, at the same time as it is being picked up) if the proper facilities exist on site; otherwise it may be obtained by users within two to several weeks. Currently, developing countries with receiving facilities can receive weather images once every 12 hours. Within a few years this will be increased to once every one-half hour. Used in conjunction with Landsat imagery, weather satellites provide an important input to regional scale studies of the effects of climate on an environment.

Multi-stage remote sensing from different altitudes (Fig. 5) is an important survey method. The area within a 34,225 km^2 Landsat image can be photographed at one or more lower altitudes to obtain better resolution and detail for verification and selective sampling. Field operations for collecting information on the ground are also essen-

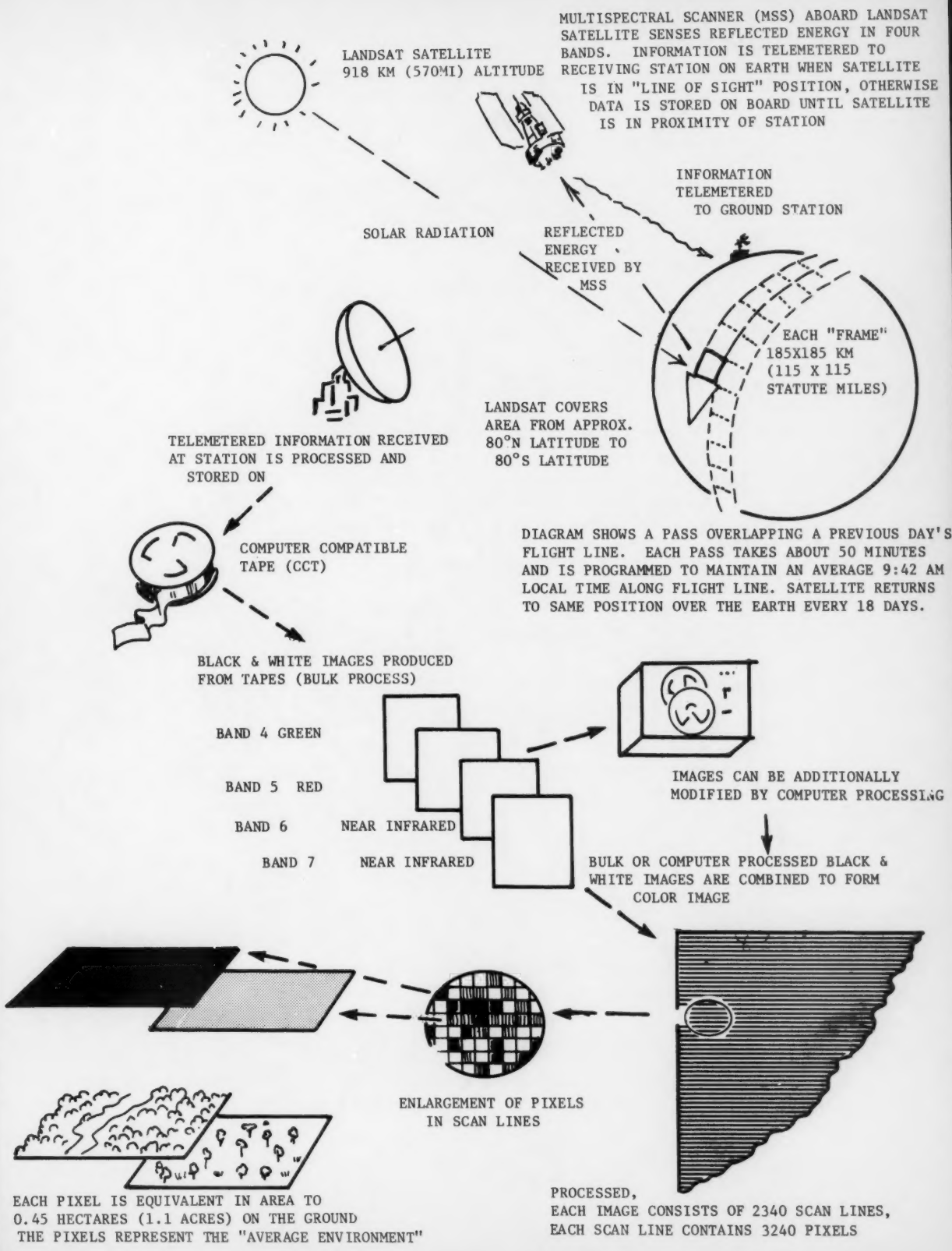
LANDSAT SATELLITE
918 KM (570MI) ALTITUDE
MULTISPECTRAL SCANNER (MSS) ABOARD LANDSAT SATELLITE SENSES REFLECTED ENERGY IN FOUR BANDS. INFORMATION IS TELEMETERED TO RECEIVING STATION ON EARTH WHEN SATELLITE IS IN "LINE OF SIGHT" POSITION, OTHERWISE DATA IS STORED ON BOARD UNTIL SATELLITE IS IN PROXIMITY OF STATION
INFORMATION TELEMETERED TO GROUND STATION
SOLAR RADIATION
REFLECTED ENERGY RECEIVED BY MSS
EACH "FRAME" 185X185 KM (115 X 115 STATUTE MILES)
LANDSAT COVERS AREA FROM APPROX. 80°N LATITUDE TO 80°S LATITUDE
TELEMETERED INFORMATION RECEIVED AT STATION IS PROCESSED AND STORED ON
COMPUTER COMPATIBLE TAPE (CCT)
DIAGRAM SHOWS A PASS OVERLAPPING A PREVIOUS DAY'S FLIGHT LINE. EACH PASS TAKES ABOUT 50 MINUTES AND IS PROGRAMMED TO MAINTAIN AN AVERAGE 9:42 AM LOCAL TIME ALONG FLIGHT LINE. SATELLITE RETURNS TO SAME POSITION OVER THE EARTH EVERY 18 DAYS.
BLACK & WHITE IMAGES PRODUCED FROM TAPES (BULK PROCESS)
BAND 4 GREEN
BAND 5 RED
BAND 6 NEAR INFRARED
BAND 7 NEAR INFRARED
IMAGES CAN BE ADDITIONALLY MODIFIED BY COMPUTER PROCESSING
BULK OR COMPUTER PROCESSED BLACK & WHITE IMAGES ARE COMBINED TO FORM COLOR IMAGE
ENLARGEMENT OF PIXELS IN SCAN LINES
EACH PIXEL IS EQUIVALENT IN AREA TO 0.45 HECTARES (1.1 ACRES) ON THE GROUND
THE PIXELS REPRESENT THE "AVERAGE ENVIRONMENT"
PROCESSED, EACH IMAGE CONSISTS OF 2340 SCAN LINES, EACH SCAN LINE CONTAINS 3240 PIXELS

FIGURE 4: Landsat Information Sequence

tial in conjunction with any remote sensing mission; these are the "ground truth" stage of the multistage approach. They can either be done for verification of remote data, as a preliminary reconnaissance effort, or for a more detailed mode of primary information gathering. Field efforts may require extended visits to an area; or they may consist of a series of brief trips. It is best if field and remote sensing data are acquired simultaneously, at least in highly dynamic environment.

Presentation of Information from Resource Surveys

Maps, charts or graphs compiled to convey specific types of information to the user are important products of remote sensing projects. The advantage of a map over an aerial photograph or scanner image is that information is selective, and unnecessary or confusing details of the photograph or image have been eliminated. Maps are more informative to users than are the photographs or images. They may also be made to depict what photos cannot show directly such as subsurface geologic structures, etc. Almost all contemporary maps are now made from aerial photography. The disadvantage of maps is their compilation time, and in some cases their rapid obsolescence. Often, "photo maps" are prepared by adding lines on top of photographs in order to combine the best of both media.

Information can also be translated into several other graphic forms and used in conjunction with remote sensing imagery to convey information to a user. For example, statistical information can be gathered and the numbers may be graphically superimposed on any scale of imagery, photography or map, depending upon the needs of the user. A key problem in integrated remote sensing projects is to be able to quickly bring map or graphic information obtained from different altitudes, or on the ground, to the same scale as data from the remote sensor, or vice-versa.

Because surveys generate substantial amounts of highly diversified information from different sources, it must be classified, tabulated, and synthesized in appropriate ways in order to be used effectively by scientists and economic planners. For example, land qualities must be defined and graded in terms of various uses of land. Several hierarchical classification schemes have evolved over the years through the efforts of natural resource scientists in several disciplines, and are used for mapping of natural and cultural environmental features. They are one of many mapping techniques designed to convey information and provide unified order for resource analysis. Frequently these groupings of land and vegetation are designated by 3 or 4 digit numbers: the first digit is the most general classification, the second digit gives the sub-class,

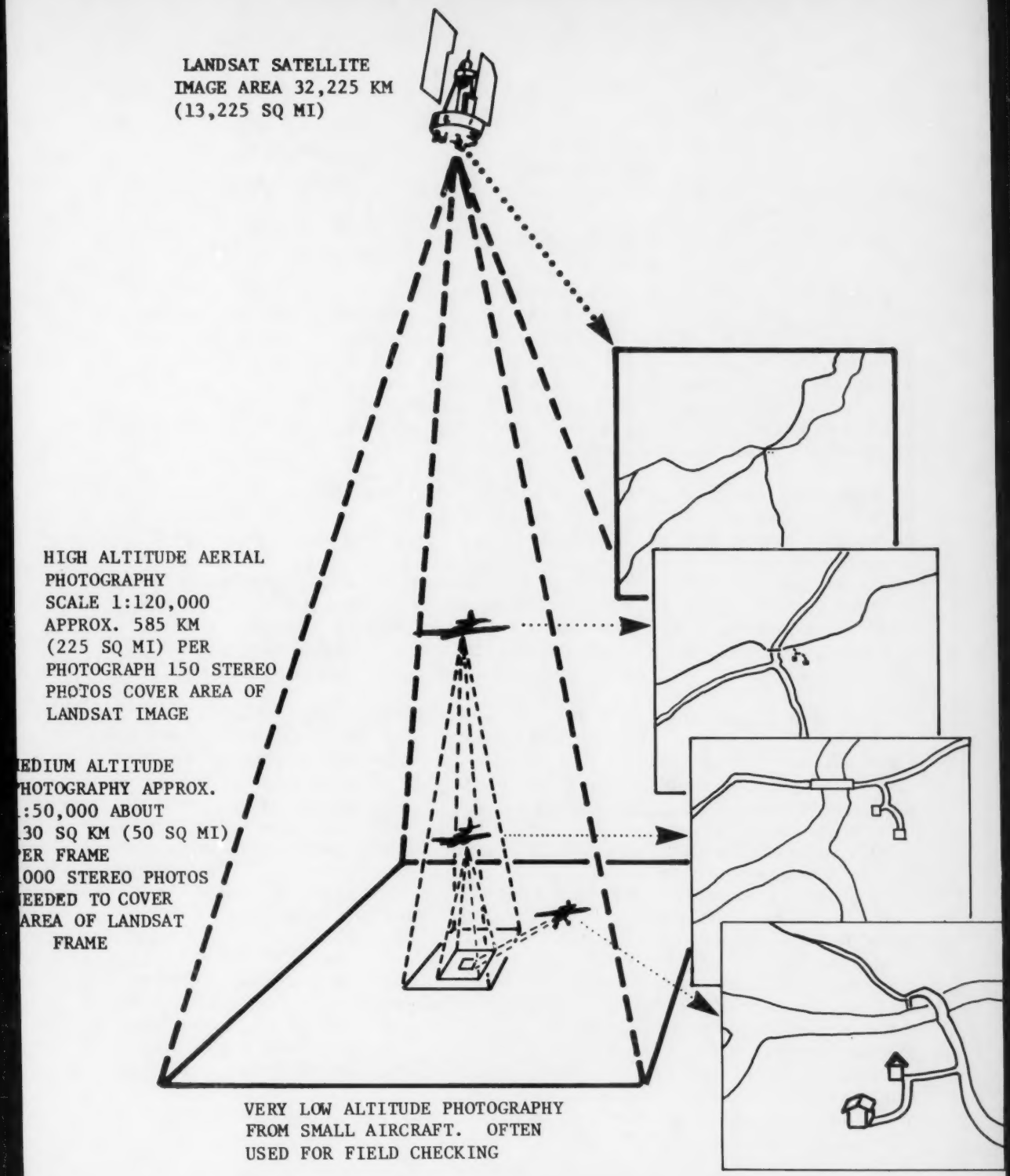

FIGURE 5: Multistage Remote Sensing

etc. Such numbers are often printed on maps to show where lands of particular types are located. As an example:

300 Natural Vegetation ...
- 310 Grasslands . . . . . 311 Annual grasses; 314 Perennial grasses
- 320 Bush lands . . . . . 321 Deciduous bush; 322 Evergreen bush

When such a classification system has been worked out, and the data classified accordingly, the locations of particular land classes can be indicated on a map either by placing numbers within boundary lines on the map, or by using colors to show land classifications. Such a map would show, for example: which areas were suitable for crop cultivation, which were suitable for livestock ranges, which were best left with tree cover--either because forestry is advantageous or because the removal of trees would destroy the soil.

Map information can be organized by using transparent plastic overlays to be placed over the basic maps. Each overlay would emphasize particular kinds of information. For example, in a water development project the basic information can be classified and mapped in the form of watershed characteristics such as drainage density, topography (using contour lines to show altitude), surface geology, soil types and vegetation. Further types of information can be added into the system within the same landform units in a subordinate manner by overlays showing, for example, roads and buildings, and local government boundaries.

Figure 6 illustrates some of these possibilities. On the block diagram at the base is a sketch of two kinds of landforms, an area of hills and a flood plain. "A" indicates how these may be shown on a contour map. "B" gives some examples of a pictorial legend showing vegetation and land forms, which could be placed on "A" in appropriate areas. "C" is simply an overlay with a rectangular grid, with numbers to systematically indicate location; this would be used in conjunction with tables in which data are organized under their location numbers. This can then be stored in computerized form, so that information about "cells" (particular squares on the grid) can be quickly found and combined or analyzed for planning purposes.

These are some of the products of remote sensing resource surveys that the people responsible for guiding development plans or deciding on the desirability of projects will have available to them in an increasing number of countries. Remote sensing can obtain in a short time, and often at much lower cost, the kinds of information that are badly needed. But it is important to develop a familiarity with these presentation methods, to become accustomed to their appearance to understand

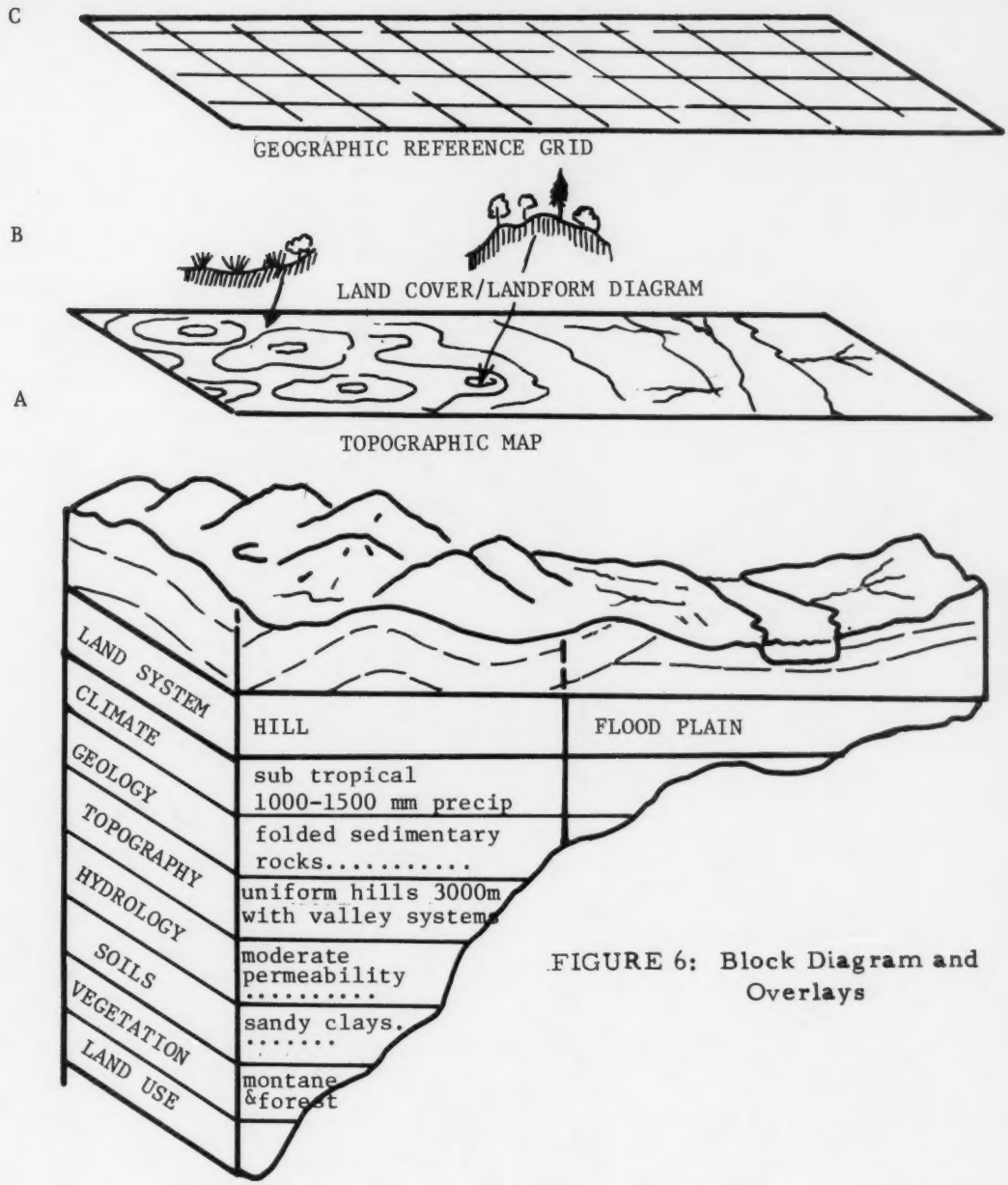

FIGURE 6: Block Diagram and Overlays

what a particular type of image or map can tell the observer, and also what its limits may be. Resource survey projects can only be of value when their contents are clearly comprehensible to those who must use them.

[Adapted from an original unpublished article.]

Figure 7: The Gezira Agricultural Complex south of Khartoum in the Sudan. The White Nile appears at the left, while the Blue Nile can be seen in the upper right. The appearance of the Complex on the right, which sharply contrasts with the surrounding arid area, results from an irrigation system. (Photo: Earth Satellite Corporation)

DRINKING WATER

WOMEN COLLECTING WATER ON THE OUTSKIRTS OF ACCRA, GHANA. (PHOTO: UNITED NATIONS.)

Patterns of Domestic Water Use in Low-Income Communities

Anne U. White

[The ways in which communities use water in developing countries differ in the rural and urban areas, and also depend on whether rural inhabitants are clustered or dispersed, and whether urban inhabitants are in central or in peripheral "squatter" sections of cities. It is important to understand the processes of choice of source and use under each of these conditions if water supplies are to be improved.]

Volume of Domestic Water Use

The volume of water used by the people of tropical developing countries is chiefly a function of income and materi al wealth, with only the highest income group having access to large amounts of safe water. The costs of that usage include the individual costs and benefits which stem from health and economic effects and influence community well-being. These two elements of cost are both associated with the volume used and with the settlement pattern of the people.

The volume of water used by rural consumers without tap connections or standpipes ranges from a daily mean consumption per person of a little over a liter to about 25 liters. For city or village dwellers who use public standpipes or fountains the consumption is about 10 - 50 liters per person daily; 15 - 90 liters for those with only a single tap in the household; and 30 - 300 liters for those with multiple taps in the house. In most low-income communities, both rural and urban, facilities for water range from no public service at all, through pubic standpipes, to instances of adequate piped supply. Water that has to be fetched from a source outside the home assumes quite a different role in the day of a householder than that obtained with a twist of a wrist

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from a tap, and carrying water is the daily lot of most women and many children in these communities.

People on the lower end of the income scale in developing countries reside for the most part in rural areas, either in clustered communities or in scattered residences, or in city peripheries where urban services are scarce or completely lacking. In these three types of settlement water for domestic use is often costly in terms of cash or energy expenditure, and its quality varies from safe to extremely hazardous. An attempt will be made here to show how domestic water is used in these different kinds of communities, and how the characteristics of use relate to the possibilities of improving the supplies.

The Population Involved

The most complete recent estimate regarding domestic water supply in developing countries has been made by the World Health Organization (WHO) in 1973, based on a questionnaire sent out in 1970 to 91 selected countries, covering about one half of the population of the world and using each country's own national definition of 'rural' and 'urban'. These estimates show that about 50% of urban residents had water connections to the house, and another 19% were served by community standpipes; but only 12% of rural residents had an adequate water supply. About 31% of the urban population and 88% of the rural population of these countries did not, in 1970, have a reasonable access to what WHO defined as safe water, which includes treated surface water or untreated but uncontaminated water from such sources as protected boreholes, springs and sanitary wells.

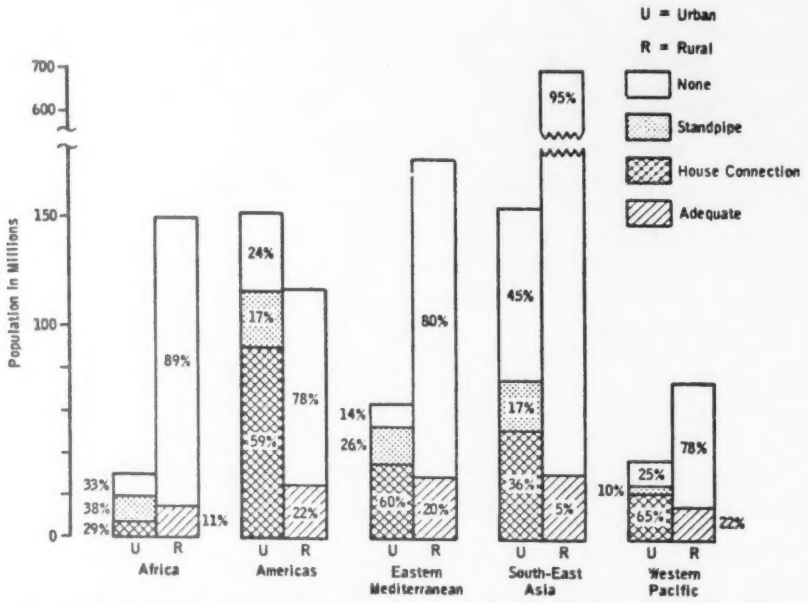

Figure 1 WHO estimates of population of developing countries in tropical areas with adequate water in 1970, by region (WHO, 1973)

Settlement Patterns

Patterns of water use and wastewater disposal, health risks, and the cost of obtaining water may be roughly judged from the literature and observation to vary according to the settlement patterns of people in developing countries along the lines indicated in Table 1.

Table 1 Characteristics of settlement and water supply

Pattern of settlement	Types of sources available	Health hazard from water	Cost (in energy or cash)
Urban peripheries	Taps	low	high
	Standpipes	medium	medium
	Vendors	high	high
	Surface—ponds, streams	high	low
	Underground—springs, wells	high	low
	Rain-barrels	high	low
Rural clustered	Taps	low	high
	Standpipes	low	medium
	Vendors	high	high
	Surface—ponds, streams	high	low
	Underground—springs and	high	low–high
	shallow wells, deep wells	low	low–high
	Rain-barrels	medium	low
Rural scattered	Surface—ponds, streams	high	low–high
	Underground—springs, wells	low	low–high
	Rain-barrels	low	low

Despite statistical difficulties, a rough estimate can be made of the proportion of people in rural areas of developing countries who live in concentrated settlements, those who live in scattered or dispersed households, and those who live on the peripheries of the large cities. G. F. White has made rough estimates of the distribution of water services in 1970 according to settlement patterns. He defines classes of settlement as follows:

Cities: Organized urban areas and their satellites.

Peripheries: Disorganized shantytowns, bidonvilles, barrios, and other (one hopes) temporary living areas on the fringes of cities.

Rural--clustered: Settlements, primarily for agricultural purposes, of households grouped together.

Rural--dispersed: Widely scattered households lacking grouping and nuclei.

Almost all the community water service which has been developed in

rural areas has gone to the clustered settlements, leaving dispersed rural households to find their own water supply. Those who live in the peripheral areas of the cities have little better access to safe water than their isolated cousins in dispersed rural settlements, while most central city dwellers have access to some form of community water.

These settlement types can be roughly grouped according to the health risks from the water used. The population of the urban peripheries may have access to a fair quantity of water from standpipes or from local streams or ponds, but their health risk from crowded conditions leading to contamination and from poor waste disposal facilities is likely to be very high. Those in rural concentrated settlements often have access to convenient supplies, depending in part upon whether they are in a humid or dry area, but because of the closeness of their neighbors and the larger numbers of people using any one source, their health risk may be fairly high, and their waste water disposal may cause problems of contamination and insect breeding. In the scattered rural homesteads, access to sufficient water may well be a problem; but when few people use each source there tends to be less health risk, and disposal of waste is much less of a problem. These are broad generalizations, for within each group sources vary, and the health risk and costs vary with them.

Water Use in Different Types of Community

Rural Concentrated. A "village" is a very different entity in different parts of the world, ranging from the settlements in Peru made up of 100-200 people which contain some 16% of the rural population of that country to the villages of India, containing thousands of people, where about 80% of the rural population live. Each country has its own census definition of "rural", and many rural villages are usually included in it. Rural regions of the developing world differ considerably in the availability of safe water (Figure 1). The Americas and Western Pacific are ahead of the rest of the regions, with nearly one quarter of their rural people having "reasonable access" to safe water. This term is defined by WHO as implying that "the housewife or members of the family do not have to spend a disproportionate part of the day in fetching the family's water needs".

The main difference that "reasonable access" can make to the householder is in the saving of time and energy in fetching it, for the volume she uses and her patterns of use once she gets it do not seem to change very radically unless water is available piped inside the home with several taps, in which case the volume used does increase considerably. In Tanzania, where D. Warner made studies

before and a year after the installation of improved water supplies which reduced the distance from the source for most households, the quantity used increased, but not by more than a few liters per capita daily. The lower the initial use, the greater the increase with the more readily available supply.

It is likely that design criteria used for rural water systems often overestimate the demand, and thus increase unnecessarily the cost of the system. In a study of 14 communities with newly installed piped supplies and without alternative supplies in north-east Thailand, ranging in size from 800 - 5000 inhabitants, R. J. Frankel and P. Shouvanavirakul found the range of consumptive figures used for design purposes to be 50 - 80 liters per capita daily (lpcd). Actual use they found to vary from 9. 6 - 86. 8 lpcd at standpipes, and 24. 4 - 65. 2 lpcd for house connections. This led them to believe that design figures of 25 lpcd for standpipes and 50 lpcd for house connections would be more realistic.

In most of the concentrated settlements water is available within about half an hour's walk, according to what sparse information is available. This is not everywhere the case. For example, in 1969 a survey revealed that out of 576,000 villages in India, about 90,000 (16%) have no water within a radius of 2 kilometers, or have wells more than 15 meters deep. Since women with water tend to walk at about 4 kilometers an hour, their trip would take them an hour, plus considerably more energy expenditure if the water has to be lifted from a deep well.

The sources available for people in concentrated settlements are varied, and frequently there is some choice of sources. In the Americas the public fountain is usually the first step in the improvement of water supplies, and up to half the population of this type of settlement in the region may have access to them. Here the housewife has a trip of relatively short duration, unless she has to spend a long time in a queue waiting her turn. Other sources include various kinds of surface water from springs, hand-dug shallow wells, and deep tubewells. In some communities rainwater is collected from the roof into containers. Except for the tubewell, or the rain-barrel in sparsely populated areas, the sources tend to be hazardous to health unless they are protected or their water treated. They may be used for washing clothes, people and animals as well as for drinking.

In these relatively crowded settlements wastewater, even with the limited amounts used, may become a problem. The easiest disposal is out the door, but in humid areas this may lead to pools where mosquitoes breed. Where there are open drains for wastewater, as in India, their load of human and animal waste can contaminate the groundwater.

As I. Burton points out, there is tremendous ingenuity in the ways that pre-industrial societies have devised for lifting, storing and transporting water. Devices such as the shaduf, the Archimedes screw and various animal-powered methods serve to lift the water; it can be stored in hafirs or tanks, and bamboo pipes, canals or qanats may transport it where needed. These devices exist alongside modern water supply technology and, if new systems do not seem to be workable, there is considerable evidence that people will return to the older method.

Rural Scattered In many of the rural areas of the Americas and of Africa settlement is scattered, with single households or small groups of households spread over a wide area. In humid areas of this type water may be readily available at short distances from the house; and even in the dryer areas there may be springs, wells, sometimes a borehole, and the variety of potential sources associated with a river--the stream itself or holes dug near the main channel. In addition there is rainwater collected from roofs or trees, or in dug ponds or tanks which last at least into the dry season. The household that is remote from neighbors may even have its own exclusive well or spring and, consequently, little contamination except from its own wastes. Such areas may also have households at the extreme limits of distance from a water source, as in the Dongore area of Ethiopia where in the dry season people have to go 5 kilometers or more to the only available source.

Water fetching does much to determine the structure of the day for the woman in the household. Usually she has to go for water first thing in the morning and again during the day. A diagram of water use (Figure 2) at two sites in East Africa shows how it fits into a woman's use of time. At Alemi, in the Lango district of Uganda near the River Nile, the land appears swampy; but for three months of the year the women have to dig holes in the edges of the swamp, or walk from their widely scattered households to a government borehole. The household illustrated contains six people, with only the mother and daughter carrying water. The mother made three trips this day to the borehole, one in the morning and two in the afternoon, and the daughter one. Each trip takes her only about ten minutes, although some of the family's neighbors may be half an hour's walk from any source. The trip is strenuous, however, for she uses a large tin container holding about 40 kilograms of water. The largest volume of water is used for bathing, although people bathe also in streams and ponds. Cooking claims the next largest volume, with enough left for dishwashing and drinking. Water is stored in a covered pot in the house.

In the second household at Mkuu, a farming community on the green slopes of Kilimanjaro in Tanzania, another family of six people uses a much smaller total volume of water. Here the mother sends her children several times a day to fetch water from the rural stand-

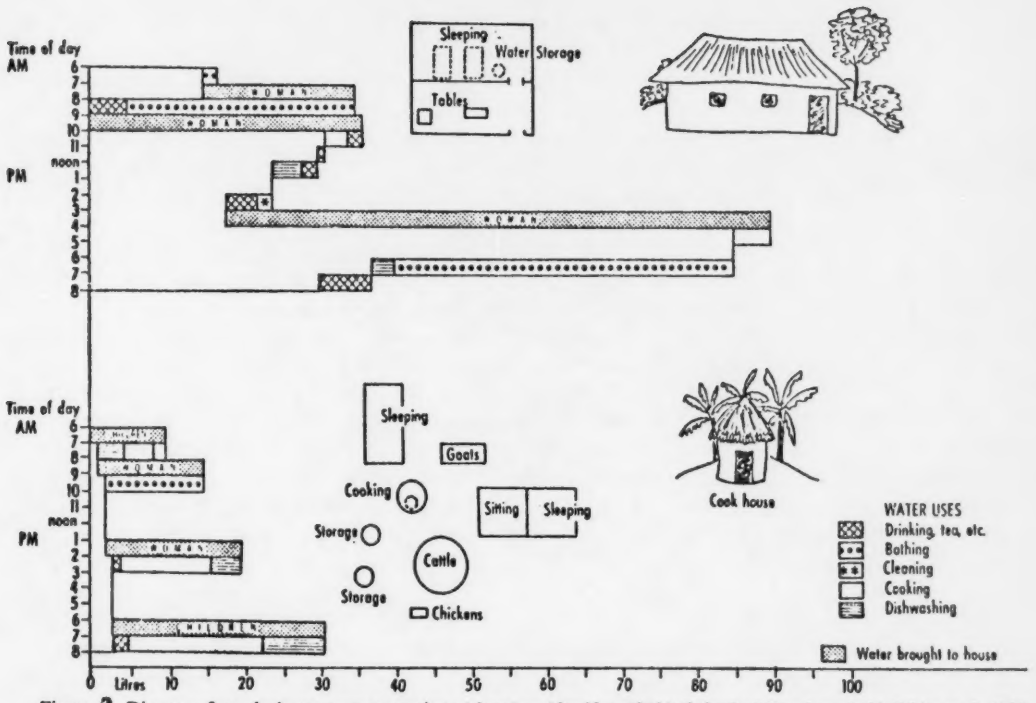

Figure 2 Diagram of one day's water use at two sites: (above) an Alemi household; (below) a Mkuu household (White *et al.*, 1972)

pipe. The water originates in a high mountain stream. They walk about 1 kilometer to this source, as she feels the little stream running near their house is not safe to use. Outside her house she keeps a 200 liter cask in which she stores water, and into this goes water from her roof when it rains, but today it is dry. Her husband's bath, and that of a male visitor, use up the rest of the water in the cask, so she makes two trips to replenish the supply. In the afternoon she sends the children off again to the standpipe. Her drinking water she keeps in a small clay pot and feels it is safe to drink without boiling. Had there been laundry to do she would have carried more water.

In both these households, wastewater was used for livestock or dumped out on the ground. Both these women are responsible for most of the food growing for their family, and have to fit their water carrying in with the rest of their daily tasks. In Africa today it is estimated that 80% of the women take a major part in the food production, carry 80% of the fuel supplies, and supply the labor for half of the house repairs and a third of the housebuilding.

Urban Peripheries Between 1950 and 1970 the number of people in urban centers of the developing world more then doubled. Assuming

that this trend continues, by the year 2000, about 43% of the population of these countries is expected to live in urban settlements. Many of these migrants have no place to live, and shelter is provided by ingeniously assembled boards, thatch, cardboard, tin scraps ,or other materials. City services are usually entirely lacking. There may be a few standpipes, each one supposed to serve very large numbers of people--1000 to 3000 in some African cities. It is more probable that a single standpipe serves some 500 people in practice (as is estimated for the city of Yaounde by Rouleau,) but even this number could involve considerable waiting time at peak morning and evening hours. Problems with standpipes also include the need for guards to prevent wastage, flooding and contamination by waste water, vandalism and the failure of equipment. The person going for water has to expect a long wait in line at rush periods, and possible disappointment if the standpipe closes or breaks before she gets her turn. In this situation people have to turn to other more risky sources; rainwater, ditches ponds, wells or streams. It is clear that they do this anyway in the wet season. In Yaounde, Cameroon, for example, the consumption of water from the standpipes more than doubles in the dry season from January to May.

Another source is the vendor who goes from house to house selling his water from a tank with a hose, or from tins on a cart. Vendors may be found in rural areas of concentrated settlement, and even occasionally serving scattered households; but they are especially common in urban areas where working people do not have the time to spend waiting at the standpipe, or where, as in parts of Asia and Africa, women do not care to be out on the streets. The costs are very high for a limited amount of water of dubious quality, and often a family buying water in this way will pay in a month as much as or more than a city dweller with a tap in his home providing a much greater quantity of safer water.

Where people are crowded together, and the fight for desired employment often requires a clean shirt and a neat appearance, the city dweller is hard pressed to be able to pay these sums for water. Despite the cost, the urban dweller without piped supplies tends to use more water than his rural cousin in the same situation. Even where there are standpipes, the water agency seldom provides the washing places, public baths or toilets which make life easier, as these facilities are usually not within its administrative bounds.

Factors Affecting Water Use Patterns

Water use patterns have been described here in three types of settlement patterns, but it should be remembered that they are very much intermixed. The woman who carries home 40 liters of water to supply

her family of four for 24 hours may be within hailing distance of a family with a tap in the house. One common characteristic of the low-income communities is that there is much more necessity for choice of source than in the higher-income areas where piped water serves almost everyone. Recently there have been some studies seeking to determine what factors affect the actual choice of source, the quantity of water used, and the ways in which it is used. These studies are still few in number, and do not cover the globe by any means, but there appear to be some general findings emerging.

There is considerable evidence that a woman in selecting her source picks what she considers the best quality for her family. Whether it is the Raiapu Enga of New Guinea who consciously avoid the water of one warm and turbid river in favor of two (bacteriologically) cleaner streams, or women in the bustees of Calcutta who use tank water for washing but not for drinking, or villagers in north-east Thailand who prefer rainwater for drinking, a judgement regarding quality is made. A user's criteria may be more likely to reflect taste, temperature, odor and appearance than precise knowledge of bacteriological quality.

Cost, in terms of the distance walked, cash payments, or time spent waiting in a queue seems an important factor in the choice of source in all areas. However, such costs do not seem to determine the amount of water carried home, and there is no entirely satisfactory explanation of why one woman will struggle home with 40 kilograms of water on her head while another is content with much less. There is some evidence that the amount of water carried from a standpipe does decrease slightly with distance, but this may simply indicate that alternative sources--puddles and rain-barrels in this case--are used to a larger degree. The volume of water used by people who carry it home seems to be associated with the number of people in the household in a variety of cultures: the larger the household, the smaller the per capita use daily. This may have something to do with the make-up of the household and who carries water; but as it also seems to hold true for the low-income families with piped water supplies in a city, it may be related to lack of access for any one individual in a crowded household to the water.

One of the major factors affecting the quantity of water used in a household is whether the washing is done at home or not. Where rural water schemes have been introduced in Latin America there are often clothes washing facilities associated with them, although in urban low income areas of Africa this is seldom the case. People often carry clothes to the source to wash them, as in the tanks available in towns in south-east Asia, or to a special spring as in Nandi

country in Kenya. The closer they are to the source, the more they tend to use it for washing clothes. D. Warner observed that about one-fifth of the water drawn from a standpipe in a Tanzanian village was used on the spot or wasted.

Other considerations include technology--the need for a bucket, a strong arm on the borehole pump handle, or a gutter connected to the rain-barrel. A woman must also allow for the fact that when she gets to a source the pump may be broken. The normal assumption in both Bangladesh and Thailand, for example, is that 50% of the hand-pumped tubewells will be out of order at any one time - as 45% of the standpipes were in the city of Dakar in 1968. Personal relationships may enter into the choice of source also: on the walk to get water a woman might encounter undesirable contact with people, or might find enjoyable social contacts.

There is one aspect of the situation that is not immediately apparent. In almost all parts of the world where water is carried it is the woman who does most of the carrying. It is also true that in most of the developing countries it is the man who makes most of the decisions for the family. This means that while the woman may have control over some of the considerations in choosing a source, she does not control all of them. For example, the man usually decides where a house will be placed, and rarely is it with regard to how long a walk it is to the water source. The quantity of water a woman must carry in a day is influenced very much by her husband's bath habits. In both the rural and urban situation, the woman rarely has much control over the family income, so she may be restricted as to whether she can use cash to buy water from a vendor, or to join in a community water supply improvement scheme, or whether cash investments can be made for an improved well or for gutters to catch water from the roof. The woman's position can also affect the result when unsatisfied demand for more or better water becomes translated into community pressure for improved supplies. Here the woman may be the one feeling the dissatisfaction, but usually she has no direct voice in community affairs, although she might be able to influence a local council through her husband. This, of course, is true for many other areas of her life.

The role of education and public information in this process is not altogether clear. As noted, dissatisfaction with either quality or quantity of water may come from the user's own perception, or it may grow out of an awareness stimulated by education and information. There is evidence that people with individual water systems tend to be satisfied with the water supply they already have, despite dubious quality, even in the highly industrialized countries. M. N. Baker pointed out that boiling and filtering through sand were both

known to the Egyptians by about 2000 B C as methods of purifying water, and that the technology for improved quality of water supplies was known in western countries long before it was in much demand. There is reason to believe that gradual stages in improving water supplies lead people to demand larger quantities and somewhat better quality. The increased desire for better service then seems to lead to an increase in the willingness of the population to pay for the improvements. David Donaldson estimates that, in Latin America, for a basic water system to go from all public fountains to about 80% of house connections has taken about eight to ten years and a constant promotional effort.

The patterns of domestic water use described here cover the majority of the people in the developing countries, some 1200 million of them, who live in rural areas and on the fringes of large cities and do not have access to adequate supplies of safe water. The prospect is that their numbers will increase in the future despite current improvement programs which, if continued at present levels, will not keep up with population growth. This makes imperative a better understanding of the processes of choice and use that influence the acceptance of new programs and the willingness to support ongoing systems.

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Rural Water Supply in Latin America

David Donaldson

[This article describes methods which have been found most successful in the extensive drive to improve rural water supplies in Latin America. Requiring local participation in building and financing water systems, and reliance on local water boards, are important.]

By signing the Charter of Punta del Este in 1961, the governments of the Americas adopted the goal of supplying water and sewerage to at least 50% of their rural population by the end of that decade. At the time they were set, these goals represented an unparalleled challenge, for only about 8 million rural dwellers (7% of the total rural population) had adequate water supplies. It was obvious that many tens of thousands of projects would have to be designed and built to bring water to the target population of 64 million people. The best data available show that by the end of 1974 the countries of the region had raised the proportion of rural dwellers having a potable water supply from about 7 to 26%. This means that about 33 million rural inhabitants are now being served by approximately 30,000 systems that they themselves helped national programs to build.

Types of Rural Water Supply Program

There has been a tendency in the past to lump

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various programs under the single heading of rural water supply. However, three separate and distinct types of "rural" program should be distinguished:

1. A protected spring or well. The most basic program - an individual source program - involves developing a protected spring or providing a well with a hand pump to serve a number of scattered families. Little or no formal community structure is associated with its operation. It is usually maintained and paid for by a national program or a ministry at no cost to the user.

2. A rudimentary aqueduct. The second program, that of rudimentary aqueducts, utilizes a well or spring, a small storage tank, and a limited distribution system for delivery of water to public fountains and perhaps a few patio connections in order to serve a semi-concentrated population. The users of such a system pay a small sum for current expenses, but depend heavily on the national program to assist them in maintenance, operation and future expansion.

3. Water in every house. The third program is the one most people are referring to when they talk about the "rural water program of the Americas". It is usually designed to serve a community with a central core of at least 100 houses, and the immediate surrounding area. The system normally utilizes a protected spring, a pumped well, or a treatment plant, and delivers water to a storage tank. Its distribution system is designed to supply water through "house" or "patio" (i. e. close to and outside each house) connections, making minimal use of public fountains. A local water board - with the assistance of the national program - operates, maintains, and administers the system and collects water rates.

Each of the three programs is part of an interrelated process. The community wells serve to attract the surrounding people, and with time the nearby population density grows. When the density becomes high enough, a rudimentary aqueduct can be considered. In the past the change-over from well to rudimentary aqueduct took an average of 12 to 15 years, while the next step - from public fountains to about 80% patio connections - took an average of eight to ten years. It is felt that progress from one stage to the next could be speeded greatly if coordinated efforts towards individual sources, rudimentary aqueducts, and patio systems were to replace the independent rural programs we have often had in the past.

In most programs hand pumps are only an intermediate goal, with piped water a long-term one. While they have their place, and many tens of thousands have been installed, our assessment of the problem in the Americas has indicated that the best approach - the one that gives the most water to the most people at the lowest cost, from the very limited financial and human resources available to us, while at the same time obtaining the most benefits for the most people - is that of piped water systems developed, built, and operated with strong local participation.

Fundamental Concepts

Despite differences of scale and technique, the various "rurban" programs of the Americas have much in common. [The word "rurban", combining rural and urban, may be understood as referring to relatively clustered or concentrated groups of rural people, as in a village.] For instance, they have all been based on three fundamental concepts. These are:

1) strong and active community participation in the development, construction, administration, and financing of the local systems;

2) focusing of resources on the problems of concentrated instead of dispersed populations;

3) extensive use of technicians to assist a limited number of professional personnel.

Other common features include the criteria used to select target communities, the methods used to finance projects, the widespread use of "mass approach" techniques, and the use of local boards which administer and operate the systems.

The criteria for selecting target communities and scheduling the construction of systems are determined at the national or regional level after a review of existing manpower and financial constraints. The criteria used by one of the most successful programs for choosing target communities were the following: 1) communities with the largest number of inhabitants (not more than 2000); 2) communities with access by road for trucks; 3) communities that have expressed interest, have requested a water system, and have offered financial or other assistance for its construction and operation; 4) communities located within one of the zones of influence of the national or local development plan; 5) communities where the project can avoid unusual or expensive solutions.

In practice, the criteria were not applied in a rigid manner but were used as guidelines. It was later found that selections made in the "project identification" phase were adhered to about 70% of the time. Failure to meet the third and fifth criteria was found to be the main reason for removing communities from the list.

Establishing a local water board. Once the community has been selected, the program promotors assist the community leaders to organize and conduct their campaign to elect and establish a local water board. Its responsibility is to obtain a community contribution of labor and/or cash which will serve to reduce construction costs,

and to organize and supervise the community's efforts to build the system which has been designed by the national/regional program. Too often it has been concluded that "poorly educated" rural people lack the required skills to construct, operate, maintain and administer their own water system. But it has been shown time and again that with proper guidance community leaders can make meaningful choices, motivate others, and provide the leadership required for success.

Once the system is completed, the day-to-day operation, administration, and financial matters for the individual systems are turned over to the locally elected water board (usually president, secretary, and treasurer). They receive technical and financial advice and assistance from the central program on a periodic and/or need basis. The cost of organizing this board was estimated in 1969 by one program to be around $320 (including the proportional costs of ministry of health personnel used at central and local levels, and the costs of training the system operator as well as the board members) and took about two months. During the first six months the program maintained a close watch on their activities, but then reduced the supervision to about one inspection trip per two or three months. The cost of the initial period was estimated at $26.60 per month, which then dropped to $8.00 per month/per board.

Community Participation in Program Financing The construction cost of a system has usually been broken down as follows: about 50% is covered by a loan from an international agency, which is often repaid by the central government; about 30% is granted by national and state programs; and the remaining 20% is obtained from the community in the form of cash, materials and labour during construction.

Programs for water supply have obtained and disbursed US$116.2 million from the 26 loans that international credit agencies made in this field between January 1961 and December 1974. For each loan there are national matching funds of 40 to 60% of the loan, and the government often contributes 20 to 30% more in construction grants and an additional amount for operational funds. It has been estimated that about $651 million was invested in rural water programs between 1961 and the end of 1974; about 82% of this has come from national sources.

In general, the operating and administrative costs are paid by the community, together with an additional amount which can serve as a reserve or help amortize loan costs. These revenues are obtained through water rates collected by the local water board under the direction of the national program. The basic financial responsibility is thus a local one, but it is carefully watched, supervised and coordinated by the national program which carries out financial planning for the program as a whole.

Areas of administrative responsibility. The functions of the various levels of a typical rural water program and the major areas of responsibility are as follows:

1) At the national level
   * Provide a financing channel for national counterpart funds, international loans, national grants and local contributions
   * Conduct long-range planning; develop norms and policies (technical and administrative)
   * Supervise the execution of the national and regional programs, and coordinate construction efforts
   * Exercise overall financial control
   * Provide technical and administrative assistance and training

2) At the regional level
   * Supervise the construction, operation and administration of projects
   * Undertake community promotion and supervision of projects

3) At the local level
   * Adminstration and operation of system
   * Maintenance of system
   * Collection of water rates

A revolving fund to finance community projects. In order to implement techniques which will permit low-cost solutions, it is necessary to establish sound long-range financing for rural water programs. The revolving fund appears to offer the best possibilities in this regard, because of its flexibility and its adaptability to local conditions. A formal definition of the term would be: A fund that is continually replenished as it is used, by income generated by the activity that it financies. For rural water programs, a revolving fund implies the establishment of a fund on a regional or national level to finance the construction of individual community projects with loans to the communities. The funds are recovered by having the benefited community repay loans into the revolving fund. As the repayments come in they are reloaned to finance additional projects. Methods for obtaining the original financing, terms of the loans, and terms of repayment can be adapted to local conditions.

While the style of the revolving funds used has varied from place to place in Latin America, the fact that they require a repayment scheme has tended to promote effective organization at the local level. The communities (as well as local and national officials) thus become accustomed to community financing of services received. This community involvement is one of the major benefits that result from the establishment of a revolving fund.

A recent World Bank study of conditions in Latin America indicates that it

is feasible to expect a "rurban" family to pay for the operation and maintenance of a typical rurban water system, and for the capitalization of at least part of the total investment. Our experience indicates that the rate necessary would equal 4 to 5% of the minimum monthly salary of the area. For this to be feasible, a rurban program should be based on communities in which 80% of the inhabitants have house connections installed at the time of contruction and paid for in the water rates. In addition, the active participation of the community in the promotion, construction, operation and maintenance of the system is essential. Without community participation, funds often become little more than construction funds which "revolve" only once.

A rural water supply package

The need to increase the output of the various programs has led to a mass or "systems" approach of which the objective has been to develop a coordinated and integrated "packaging" of those concepts that permit a more rapid promotion, design, installation, operation, maintenance, and administration of the various projects. Under this systems approach, a rural water program is broken down into its various elements - promotion within the community, technical design, program financing, etc. - and each is studied for its effects on the others. A model is then developed which coordinates all of the elements in such a way that they will focus on the desired goal: a mass-scale program that will result in rural water systems that can and will be operated, maintained, and financed by the community. When a rural program must repeat the same tasks for thousands of villages, the development of "standardized" techniques and designs have been found to be essential to multiply limited resources.

The technical design of a project is prepared on the basis of existing maps or aerial photos and standardized design criteria, using predesigned elements and standardized equipment lists. The materials are assembled in a central yard and sent to the community as a package, along with all the necessary tools and items not readily available locally. Professional staff train and supervise volunteer workers at the local level to help stimulate community involvement. The more successful programs have shown that each individual system should be treated as part of a larger framework, using mass approach techniques to construct, operate and administer hundreds of systems. This means that all actions (technical, administrative, and financial) must be coordinated at the central level - without forgetting that each project also needs strong local participation.

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Health Aspects of Water Supplies in Tropical Countries

David J. Bradley

[This article classifies the ways in which groups of prevalent tropical diseases are related to water supply. More diseases are affected by water supply than is usually thought when the engineering calculations for water projects are made. The means by which related diseases may be controlled are indicated.]

The Need for Understanding Health Aspects

Domestic water supply in temperate countries is in a fortunate position. People are prepared to pay an economic price to have good water readily available, which rarely costs much of their income in any case. So the health aspects do not need to be looked at critically from an economic viewpoint, and water is provided of a quality such that risk of disease is minimal.

In the tropical developing countries the position may be quite different in the following ways: (1) People are often too poor to pay for a supply providing completely safe water through a multiple tap system in the home. (2) Governments or agencies providing funds will require clearer evidence of the health benefits to be expected, since their hope of financial returns will be smaller. (3) The funds made available may be inadequate for an ideal water supply, so that difficult choices between differing incomplete

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sorts of improvement have to be made. If these decisions are not made consciously, the situation usually arises where a very few people get excellent water supplies and the vast majority do very badly indeed. (4) The diseases related to water supplies are more numerous, more important and more diverse in the tropics than in temperate lands and effects of improved supplies are more complex.

Classification of Water-Related Infections

Between 20 and 30 different infective diseases may be affected by changes in water supply. They are usually classified, by the microbe causing them, into viral, bacterial, protozoal and helminthic diseases. But this is not very helpful in considering effects of improved water supplies. What affects them is the mode of spread, and it is useful to have four main categories: (a) Infections spread through water supplies--water-borne diseases. (b) Diseases due to the lack of water for personal hygiene -- water-washed diseases. (c) Infections transmitted through an aquatic invertebrate animal -- water-based diseases. (d) Infections spread by insects that depend on water -- water-related insect vectors. The structure of this reclassification is shown in Table 1.

Table 1 Classification of infective diseases in relation to water supplies

Category	Examples	Relevant water improvements
I Water-borne infections		
(a) Classical	Typhoid, cholera	Microbiological sterility
(b) Non-classical	Infective hepatitis	Microbiological improvement
II Water-washed infections		
(a) Skin and eyes	Scabies, trachoma	Greater volume available
(b) Diarrhoeal diseases	Bacillary dysentery	Greater volume available
III Water-based infections		
(a) Penetrating skin	Schistosomiasis	Protection of user
(b) Ingested	Guinea worm	Protection of source
IV Infections with water-related insect vectors		
(a) Biting near water	Sleeping sickness	Water piped from source
(b) Breeding in water	Yellow fever	Water piped to site of use
V Infections primarily of defective sanitation	Hookworm	Sanitary faecal disposal

Water-Borne Diseases

The classical water-borne diseases are due to highly infective organisms where only rather few are needed to infect someone, relative to the

levels of pollution that readily occur. The two chief ones have a high mortality if untreated and are diseases which a community is very anxious to escape: typhoid and cholera. Both are relatively fragile organisms whose sole reservoir is man.

Table 2 Main infective diseases in relation to water supplies

Category	Disease	Frequency	Severity	Chronicity	Percentage suggested reduction by water improvements
Ia	Cholera	+	+++		90
Ia	Typhoid	++	+++		80
Ia	Leptospirosis	+	++		80
Ia	Tularaemia	+	++		40?
Ib	Paratyphoid	+	++		40
Ib	Infective hepatitis	++	+++	+	10?
Ib	Some enteroviruses	++	+		10?
Ia, IIb	Bacillary dysentery	++	+++		50
Ia, IIb	Amoebic dysentery	+	++	++	50
Ib, IIb	Gastroenteritis	+++	+++		50
IIa	Skin sepsis and ulcers	+++	+	+	50
IIa	Trachoma	+++	++	++	60
IIa	Conjunctivitis	++	+	+	70
IIa	Scabies	++	+	+	80
IIa	Yaws	+	++	+	70
IIa	Leprosy	++	++	++	50
IIa	Tinea	+	+		50
IIa	Louse-borne fevers		+++		40
IIb	Diarrhoeal diseases	+++	+++		50
IIb	Ascariasis	+++	+	+	40
IIIa	Schistosomiasis	++	++	++	60
IIIb	Guinea worm	++	++	+	100
IVa	Gambian sleeping sickness	+	+++	+	80
IVb	Onchocerciasis	++	++	++	20?
IVb	Yellow fever	+	+++		10?

These two diseases occur most dramatically where a community water supply gets contaminated by feces from a person suffering from, or carrying, one of the infections. Many people drink the water and a number of these fall ill from the infection at about the same time. It is this sudden appearance of a cluster of cases in an epidemic, combined with their severity, that makes these illnesses so feared. Now, by and large, big groups of people tend not to share really very heavily polluted water to the point where it is obviously foul. But small rural family groups may be forced to use such water. There will be too few of these people using the same water source to be able to see a clear common-source outbreak of diseases that

depend on very heavy contamination. Therefore it is difficult to incriminate the water supplies. The limits of what are occasionally water-borne diseases are much less certain therefore, but are steadily extended as our knowledge grows. Infective viral hepatitis has only in recent years been shown unequivocally to be sometimes water-borne, for example. It is also important to realize that epidemiological conclusions are not universally applicable in this matter: in temperate countries typhoid is almost exclusively water-borne; but in the tropics this is less often so, and evidence of water spread in the rural tropics is often absent.

Typhoid is the most cosmopolitan of the classical water-borne infections. In man it produces a severe high fever with generalized systemic, more than intestinal, symptoms. The bacteria are ingested, and very few are sufficient to infect. There is a considerable typhoid mortality in developing countries, though early diagnosis and adequate therapy with (expensive) antibacterial drugs can greatly reduce this. Prevention by immunization is possible. The typhoid patient is usually too ill to go out polluting the water and is not infective prior to falling sick. However, a small proportion of those who recover clinically continue to pass typhoid bacteria in their feces for months or years; these carriers are the source of water-borne infections. Typhoid bacteria survive well in water but do not multinly there: they are removed by standard slow sand filtration, and killed by chlorination.

Cholera is in some ways similar to typhoid, but its causative bacteria are more fragile and the clinical course is extremely dramatic. In classical cholera the onset of diarrhea is sudden and its volume immense so that the untreated victim has a high probability of dying from dehydration within 24 hours or little more. The infective dose is quite large, but pollution levels in endemic areas are very high with immense fecal volumes full of bacteria, and in dense human populations. Within a few days the classical cholera victim of South East Asia is dead or non-infective. With the now almost cosmopolitan El Tor strain, which has a lower mortality, convalescent carriers occur and numerous other people are infected without becoming ill so that the chance of spread is increased. Immunization is protective but only for a few months, so that improved water and sanitation is the most useful control measure.

Several other infections are water-borne but are less important than typhoid and cholera. Leptospirosis, due to a spirochete, has its reservoir in wild rodents which pollute the water. Leptospires produce jaundice and fever, called 'Weil's disease', which is severe but not common. Giardiasis, which may produce diarrhea, is common in the tropics and has been shown in some temperate country outbreaks to be water-borne. The route of transmission in the tropics is unclear. Amoebiasis has a similar epidemiological picture and is more important. Spread is from one person to another by the resistant cystic stage of the amoeba and this has sometimes been demonstrably water-borne, though often it may pass from feces to

mouth via food or dirty hands. A large group of enterobacteria related to typhoid may cause diarrhea or dysentery. In the last two years, the role of a new group of viruses, the rotaviruses, as causes of childhood diarrhea is beginning to emerge. The mode of transmission is not yet known, but most high intensities of diarrheal diseases have been associated with defective water supplies.

Water-Washed Diseases

All the infections that can be spread from one person to another by way of water supplies may also be more directly transmitted from feces to mouth or by way of dirty food. When this is the case, the infections may be reduced by the provision of more abundant or more accessible water of unimproved quality. This applies particularly to the diarrheal diseases due both to bacteria and to viruses as well as protozoa. The most thorough studies, of Shigella infections in the southern United States, have shown that simply making water more available tends to roughly halve the frequency of infection.

The diarrheas are the most important water-washed diseases in tropical areas. They are responsible for vast amounts of sickness in people of all ages, in South America and South-East Asia particularly, and along with malnutrition, measles and malaria are very important in the very high child mortalities of those areas. The diarrheal diseases are responsible for the majority of the economic losses ascribed to water-related diseases in many countries. They result from a range of infectious agents, but fall to a low incidence under good hygienic conditions.

The second main group of water-washed diseases are infections of the body surface, the skin and the eyes. Though rarely shortening life, they make many people miserable. 70% of pre-school children in Ankole, Uganda, for example, had either skin ulcers infected by bacteria, or scabies due to a small mite that burrows in the skin, or fungus infections of the skin. More water, together with improved personal hygiene are needed to reduce the frequency of these infections.

The question immediately arises as to what is an adequate volume of water for hygienic purposes. Unfortunately no accurate answer is available. It seems clear from epidemiological data that a few liters is not enough, and that several hundred liters is more than adequate; but this is a great range. In practice it appears that, unless water is piped into the home, water use is not at the optimal level for health. A shower or bath needs to be of sufficient volume to remove dirt and then soap without becoming too concentrated a solution of either, and similar considerations apply to the washing of clothes and pots. When supplies are very short, the successive re-use of water for washing people and utensils may be worse than substituting sand for cleaning dishes.

In addition, the eye infections are related to water availability, and are a particular problem in arid countries where the drying effect of the air on the conjunctiva is combined with dust and sand and the scarcity of domestic water. A specific infection of the eye due to a virus-like microbe is trachoma, which may lead to inflammation, turning in of the eye lashes, and subsequent opacity of the cornea producing partial or complete blindness. Many other bacteria may follow the trachoma agent, and their relative roles in producing the frequent chronic eye lesions of the tropics is variable. Trachoma itself produces much less damage where water supplies are adequate.

Water-Based Diseases

Water-based diseases are all worm infections. Several are due to flukes or trematodes whose larvae depend on aquatic snails. The eggs pass from excreta to water, and the larvae emerging from the snails may be ingested with domestic water directly or on food plants or animals which acquire encysted larvae from the water. By far the most important, however, the schistosome worms, can bore their way directly through the human skin and they are therefore a hazard to all in contact with infective water, whether for domestic use or not. It is thus not only necessary to provide domestic supplies but also to persuade people to keep out of the water at transmission foci. In spite of some skepticism regarding the efficacy of water supply improvements as a control measure, Jordan and his colleagues in St. Lucia have found this approach highly successful.

Guinea-worm infection or dracunculiasis is transmitted through cyclops, a minute crustacean, and has a wide but patchy distribution in Africa and Asia. The adult worm lies beneath the skin, often of the leg. It matures near to the rainy or planting season usually, and the posterior end of the female comes to lie beneath a blister, usually on the lower leg. When water is spilled upon the leg the blister bursts and many guinea-worm larvae are freed, and if they are washed into a well or pond containing cyclops the life cycle can continue. To complete it, people have to drink water containing the infective cyclops. It follows that prevention may be by standard water treatment processes, or much more simply by preventing water flowing back into wells after it has been spilled. This is achieved by an outward-sloping concrete collar around the top of dug wells; these have been highly successful in parts of Nigeria in eradicadicating the infection. The important of guinea worm is great: it produces arthritis of joints adjacent to the active worm and effectively disables those infected for a couple of weeks which, because of the timing of the infection, fall at the short planting season. In affected villages the prevalence may exceed 70%.

Water-Related Insect Vectors of Disease

Many mosquitoes and other vectors of infection breed in water. Malaria, transmitted by anophelines, is only the best known of a number of diseases

carried by mosquitoes. However, the complexities of control problems, given the various species of mosquitoes and their differing habits, and also their differing capacities as disease transmitters, cannot be easily described.

Of particular interest is the urban problem of water storage jars acting as breeding sites for the 'yellow fever mosquito' Aedes aegypti. This occurs throughout the tropics, not only where water has to be fetched to the house and stored, but also where an intermittent piped supply makes for larger storage jars, not limited by the carrying capacity of the family. Such containers are the preferred habitat of Aedea aegypti. It carries several virus diseases from person to person. In the Caribbean and West Africa yellow fever, a very severe and often lethal jaundice, is the best known. Of perhaps greater current importance is dengue, an acute influenza-like illness of short duration which is endemic in many Asian cities. Under conditions of intense dengue transmission, cases of the more severe dengue hemorrhagic fever with an appreciable mortality begin to occur. The mosquitoes can be killed by putting a suitable insecticide, of very low human toxicity, into the water containers.

In rural areas the journey to fetch water may bring women into the preferred habitat of Glossina or Simulium. The former, genus of tsetse flies in Africa, has several members confined to reverine bush, so that people get bitten when going to the few residual waterholes in the dry season when man-fly contact is most concentrated. They can transmit human sleeping sickness, a chronic lethal infection if untreated. They may be controlled by selective bush clearing near the water point.

Disease of Defective Sanitation

It is already clear that many diseases in the water-borne, water-washed and water-based categories depend on access of human wastes to water or people's mouths, so that they all may be reduced by measures aimed at improving waste disposal as well as water supply. Some theoretical reasons have been advanced for water being more likely to be effective than sanitation against some water-based diseases; but the chief practical reason is that the use of new water supplies presents far fewer difficulties than does persuading people to use new sanitary facilities.

A number of infections, however, are only affected by the latter: human hookworms penetrate the skin from damp contaminated soil; and certain flukes encyst in food items unaffected by changes in water supply. The hookworms are a major problem in the damper tropics. They live in the small intestine and cause major blood losses into it, acting as a cause of anaemia, especially in populations where dietary iron is low or poorly absorbed. The less tropical of the two species may be spread by penetration of the mucous membrane of the mouth when water containing the larvae is drunk; but the more tropical one, Necator, can be prevented by sanitary disposal of feces, or by the wearing of shoes alone.

The common roundworm or Ascaris lays very numerous eggs which escape in the feces and mature in the gound before becoming infective to man if ingested. They usually get in on fingers or food; both increased water supply and sanitation reduce transmission. The adult worms are often over 10 cm long and they divert food from the human host, give rise to various abdominal symptoms, and occasionally produce intestinal obstruction. Ascaris has a relatively cosmopolitan distribution, as does Trichuris, a smaller worm that is of less significance to public health.

The various flukes whose eggs escape in the feces and which gain access to man in or on inadequately cooked food include Paragonimus, the lung fluke of South-East Asia and parts of West Africa, two liver flukes, and Clonorchis another South-East Asian parasite causing extensive liver damage. All can be controlled by thorough cooking of food or by sanitation - either standard sewage treatment approaches or leaving feces in pit latrines, or adequate storage at appropriate temperatures prior to their use as an agricultural fertilizer.

Conclusion

The relative importance of water-borne and water-washed diseases will affect supply priorities. We have indicated that increases in water use are generally beneficial up to the level at which water is piped, with a single tap and shower, into the compound or house, and that this last step is probably a crucial one. Water quality effects are more dependent on the number of people using a common source. Any fecal pollution in a large urban distribution system carries the threat of a large epidemic; but in small village systems the probability of pollution with a pathogen is reduced by the smaller potentially contaminating population, and the size of any resulting epidemic is also much smaller, so that in situations of limited funds a lower relative priority can be given to completely unpolluted supplies. Again this will depend on the environment: bacteriological quality is more pressing in a Bangladesh village in a classical cholera area than in an isolated village in Tanzania, and is crucial in the urban situation. It is hoped that this analysis of heath effects of water improvement, while providing no comforting rules-of-thumb for the administrator or engineer which would be misleading, may give some insight into the diseases he hopes to prevent and thus provide a rational basis for planning water improvements.

[Extracted from Chapter 1 of Water, Wastes and Health in Hot Climates, Richard Feacham, Micheal McGarry and Duncan Mara editors. Copyright © 1977 by John Wiley and Sons, Ltd., London and New York. Reprinted with permission.]

Water Charges

Robert J. Saunders and
Jeremy J. Warford

[It would be desirable for a number of reasons that water users pay the costs of supplying their water; but this is often difficult to arrange, especially in rural areas. Nevertheless, the effort to guide investment by community or individual willingness to pay has practical advantages.]

It is extremely difficult to predict the effects of investments in rural water supply and sanitation. This is mainly because of the problems of identifying the impact of such investments on public health, which is normally accepted as a primary objective. Improved water supplies can contribute to other objectives, such as stemming rural-to-urban drift, creating more time for productive activity, and so on; but these provide no useful guide to the merits of competing projects. Moreover, we doubt that knowledge in this area could be improved by conventional benefit-cost analysis, which would seek to evaluate water and sanitation investments by direct observation of how such services are used, and to impute to them money values based largely on the judgment of the analyst concerned. Experience suggests that in the public utilities field in general, such attempts have tended to be futile. A satisfactory basis on which to allocate funds to the sector as a whole is therefore lacking, as well as a method of ranking projects within the sector. The only way in which

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the minimum economic worth of investments can be determined is by giving consumers themeselves the chance to let authorities know how much they value the service concerned, by being charged a price that reflects the full economic cost of supply.

Economic Efficiency and Marginal Cost Pricing

An important benchmark by which policies relating to water supply may be judged is the contribution those policies make toward economic efficiency. An efficient policy may be defined roughly as one which maximizes the net benefits accruing to a community from a given course of action. The price of any service or commodity supplied by a public body should be equated to the cost of producing an additional unit of it, in other words, to its marginal or incremental cost. If consumers are willing to pay a price that exceeds marginal cost, it means that they place a value on the marginal unit consumed at least as great as the cost to the rest of society of producing that unit; output and consumption should therefore be expanded when system capacity is reached. If, on the other hand, the market clearing price is less than marginal cost, it can be assumed that there is oversupply of the commodity: the cost of additional output exceeds the benefits. While rigorous application of the theory may not always be feasible for projects in rural areas, the principles remain highly relevant. Indeed, we contend that, combined with the financial and administrative arguments for recovering costs from consumers, use of the concept of consumers' willingness to pay as a guide to resource allocation is esssential to the achievement of any noticeable improvement in rural water supply situation in the developing world.

The theoretically ideal pricing and investment rules are generally somewhat removed from the methods actually used to finance and determine the value of municipal and rural water supplies in both the developed and developing world. Water authorities are normally reluctant to make use of price as a means of achieving allocation of resources, and the inefficiencies generated by failure to adhere to marginal cost pricing rules can be extreme when the means of implementation (that is, metering) do not exist.

Benefits and Costs of Installing Meters. Where the cost to a consumer does not vary with consumption, he will continue to use water up to the point where the value to him of the last unit consumed is zero. At this point the net economic loss will be the relevant marginal cost - which, when system capacity is less than fully utilized, will equal short-run marginal cost. Inefficiency is particularly evident when, at the

current level of consumption, existing capacity is on the verge of full utilization, and for some reason rationing by price is not feasible. In these circumstances, the decisionmaker is faced with the choice of permitting shortages and allocating water by nonprice means, or of extending capacity. Rationing by physical or administrative means has become the norm in many developing countries, but this is unsatisfactory as a permanent policy. As a public utility, a water undertaking should be able to supply water to those willing to pay for it. There are also theoretical objections: nonprice rationing is a necessarily arbitrary device and can rarely be administered in accordance with the value of the benefits derived from the services rendered. It is therefore inefficient in allocating resources in the short run, and offers no guidance for the investment decision.

The policy usually preferred by decisionmakers in the water supply and sewerage sector is automatically to increase capacity when existing capacity approaches full utilization. But in the absence of a signal to invest, such as a willingness of consumers to pay a price equal to marginal cost, it can rarely be certain that the value of the additional consumption - or usage - made possible by the investment will exceed the costs thereby incurred. Where significant budgetary constraints are lacking, a failure to employ pricing and a reliance upon the "requirements" approach will almost certainly result in overinvestment. In other cases, budgetary constraints may prevail when, in terms of the costs and benefits of a given project, they should not. Either way, inefficiency is likely to follows.

Unfortunately, implementation of use-related pricing (that is, through metering) for water supply is a costly exercise, and its introduction or continuation should ideally be subject to cost-benefit analysis. Briefly, the benefits of metering are the cost-savings brought about by reducing consumption. Savings may be achieved by deferring investment as well as by reducing annual operating and maintenance costs. To determine whether the investment in metering is worthwhile, the present worth of these savings should be compared with the present worth of initial and annual costs of metering, plus the reduction in the value of water consumed. Because the reduction in consumption likely to result from metering is normally highly conjectural, one way to approach the problem is to ask the question, what percentage reduction in consumption would justify the introduction of metering? If extreme values result from such a calculation, it is easy to make a judgment as to whether or not metering is justified; if not, at least the worst excesses of installing or not installing meters may be avoided.

The case for metering industrial consumers in urban and many rural areas is usually not a matter for serious dispute; the cost of metering is normally insignificant in relation to the cost of water consumed. The real question is whether or not to meter domestic and small commercial consumers, and here the need for some sort of cost-benefit calculation is clear. The water supply industry usually argues that the introduction of metering will reduce recorded per capita consumption; but changes in price after meters have been installed generally appear to have insignificant effects on consumption. Universal metering reveals discrepancies between the quantity of water going into supply and that actually received on consumers' premises. Such discrepancies, revealing the extent of leakage from the mains and of illegal connections, provide an immediate incentive for the improvement by water authorities of waste prevention methods (prior to metering, waste would have been recorded as domestic consumption). Metering would therefore bring about a permanent reduction in annual wastage, a condition that would remain unaffected by subsequent price changes. Metering will also encourage individuals to reduce the amount of water wasted on their premises; but once having made this adjustment, their demand for water remains relatively inelastic. Both arguments would seem to be valid.

There are a number of special problems, however, which suggest that metering will rarely be appropriate for residential and commercial consumers in rural areas. The costs of metering will tend to be relatively high, for meter reading and maintenance will be more costly because of lower population density (with few people wealthy enough to have household connections). In smaller communities the meter reader may be under great social pressure to underrecord consumption. At the same time consumption tends to be lower in rural areas where people are poorer and do not have water-using appliances or adequate means of disposing of wastewater. If there is not much waste, the potential gains from conservation of water are therefore limited. Exceptions of course exist: the lower density of population may mean that more water is used for garden watering or for livestock; where this is so, metering is a more viable proposition.

Central to the problem of metering is that, because of low incomes in rural areas, the appropriate source of supply may not be household connections but rather communal standposts, or wells with hand pumps. Although in these circumstances metering in the normal sense of the term may not be an appropriate means of influencing consumption, principles similar to those outlined above should be applied to the decision to use a village or water board employee to supervise the dispensing of water from standposts, or to sell the concession to an individual. These methods are frequently used in urban areas of developing countries where standpost supplies are provided, although somewhat less so in rural areas. Conservation of water and the prevention of vandalism to taps are often cited as the reason for employee control of taps or

sale of concession.

Kenya provides an interesting example of a case in which water vendors (water kiosk operators) in a number of rural villages serve the multiple functions of generating a small amount of revenue from public taps, of limiting public tap water wastage, and of protecting the taps from vandalism. In several regions of the country villagers had not been paying the small monthly tax which was to be used to help operate and maintain their local water supply systems. Furthermore, it was financially very costly and physically almost impossible to maintain many of the public standposts because of frequent acts of vandalism on taps, drainage facilities, protective fences, and so on. As a result, in a few areas the public standposts were converted to water vendor operations in which a licensed vendor is paid a subsidized rate for the metered standpost water and sells it by the container (debe) at a fee slightly higher than he pays. The difference between the kiosk operator's buying and selling price does not have to be large because most of the rural kiosks are operated by the wife or children of the vendor, and their opportunity cost is low. The result of the switch to kiosks is that vandalism has been greatly reduced (the tap and meter are locked up when not in use), a small amount of revenue has been generated, and the rate at which people have applied for house connections has increased. (Some people presumably feel that, if they are going to have to pay for water, it might as well be convenient water.) A drawback to the system, however, is the inability of some kiosk operators to retain for any period of time the revenues collected from water sales, thereby forcing the water authority to collect its sales revenues daily from the kiosk operators, a rather costly alternative.

New Consumers or Communities. The previous section dealt with consumers who currently have a supply of water, and who may not be charged on the basis of the amount they actually consume. The question of pricing as an indicator of project benefit takes on a different complexion when related to the problem of deciding whether individual households or communities which have been relying on private sources of supply should be supplied from a public system. Here, by definition, a direct observation of the willingness of individual consumers to pay is not possible before they have had the water supply available to judge it. We would also argue that the questionnaire approach to estimating individuals' willingness to pay has been shown to be virtually useless.

As far as new communities are concerned, the approach to this problem should be twofold. First, as an example, in India and in many Latin American countries, the necessary qualification for getting a new water supply should be a community contribution, say

of 20 to 30 percent of initial project costs. Where the smaller villages are concerned, this contribution may be a reasonable indication of the value placed upon the project; the larger or less democratic the village, and the more activities that it carries on as a community, the less this proxy can be relied upon.

This screening device should be supplemented, as far as possible, by analysis of other communities in the country in terms of the observed willingness of their inhabitants to pay for water. The greater the variation in the economic, cultural, and climatic conditions of the villages concerned, and the smaller the sample of such villages, the harder will be the task of estimating willingness to pay in those areas as yet unserved. Even in these circumstances, however, this discipline is valuable for policymakers in determining investment priorities, and there is no real alternative to the procedure.

A somewhat similar approach should be followed in deciding on whether or not to extend service to new consumers in areas currently served. As far as household connections are concerned, there is no real problem - individual willingness to pay for connection can easily be demonstrated. Where the issue is whether or not to extend standposts into a new area of a community, there would be no problem if the consumers concerned had cultural and economic characteristics fairly similar to those in other parts of the community who currently had standpost supplies, and if those currently served had demonstrated willingness to pay. Where these conditions do not exist, a method of trial and error is the only course of action.

The Problem of Geographically Uniform Tariffs. There seems to be a mounting pressure for geographically uniform prices. This pressure is important, not only because of the strength of the emotional appeals for uniform water rates, but also because of the wide variations in costs of supply within relatively small geographical areas. The observed tendency toward uniformity results in part from the consolidation of the management of water authorities into large regional, state, or countrywide water boards, which is often desirable for efficiency of operation. But the replacement of a number of small water authorities by one water board often involves the replacement of many different pricing policies by one uniform tariff schedule - for no sound reason. Another explanation for the trend toward increasing uniformity is the improvement in communications, which allows residents of remote communities to become aware of the prices that consumers in other parts of the country are being asked to pay for water. It is said that a gallon of water is a gallon of water wherever it is supplied, so that a village should not be penalized if supplying it with water happens to be relatively expensive.

There are may examples one can cite of the unfortunate effects of

uniform water pricing on land use, and especially on the location of water-using factories. For example, in one African country a number of development areas, or "growth poles," have been designated. As uniform water charges are levied throughout the country, the choice of industrial location is not influenced by the cost of water. Unfortunately, the incremental costs of water for many of the growth poles are not known even by the planners. If industry expects to be faced with costs which vary according to geographical location, and when major increases above current water use are required, it should make inquiries as to expected water or other charges, thereby forcing planners to carry out the necessary cost estimates.

Other Methods of Regulating Consumption. Where direct regulation of consumption by price is ruled out, a variety of methods may be used by water authorities to conserve water. The rural water supply program in Argentina, for example, makes use of a system of individual house water tanks, both to regulate the flow of water and to charge according to the volume of water consumed. A cement tank sitting on top of each house has a small hole through which the water flows, taking a long time to fill up the tank. The inhabitants of the house can use the water in whatever quantity they want until the tank is empty; generally the water users ration their consumption over the day so that the tank is never quite dry, and it can then refill throughout the night. People pay different water charges with the size of the hole through which water enters their tank; i. e., according to whether they want tank inlets rated at 300, 500, 800, or 1,000 liters. The price charged for water varies by village but, in general, the monthly water rate for the 300-liter inlet is approximately 1 to 2 percent of the monthly income of the water consumers. This device therefore acts as a means of pricing and regulation of consumption and is probably much cheaper than metering.

Flat Rates, with Rules about Consumption. In many countries a flat monthly rate is charged for each house connection, with rules about how the water may be used. The rules sometimes specify that only the family cow, horse, and chickens may be watered with the potable water, or that certain plants or trees that consume a lot of water cannot be grown near the water tap. In most countries, different rates are charged to families that use public fountains, or standposts, than to those that have house connections. In many instances, despite the greater cost of house connections, the proportion of the village with house connections increases fairly rapidly through time. There seems to be a demonstration effect: as people begin to see the advantages of having a house connection they somehow manage to save the money necessary to acquire and maintain one. The trend is sometimes reinforced (as in several Latin American countries) by the closure of public fountains after a certain percentage of the village has house connections.

In some countries and cultures, however, the collection of monthly flat-rate water charges is difficult. Generally, arrears seem to be less

of a problem in Central and South America than in some portions of Africa where water is viewed as a special gift from God and therfore always free. Head taxes or house taxes for water in some rural areas of both East Africa and West Africa have been quite unsatisfactory, with collection rates of less than 20 percent.

Waste control. When a flat-rate water fee is instituted, water wastage can be a problem in some countries and cultures. There are essentially two means of dealing with this problem: community moral suasion, and the installation of flow-limiting devices. Throughout much of Latin America and in some areas in Asia, country officials claim that community moral suasion has been sufficient to keep water wastage within acceptable limits. A village water committee, or village council, attempts to police the water wastage problem, and if anyone persists in not turning off the tap he either barred from using the public fountains, his house connection is disconnected, or a flow-limiting device is installed at his residence.

Public standposts with some form of spring-loaded tap are relatively common. But villagers are usually quite ingenious at inventing means to tie open the tap, or somehow to fault the spring mechanism. More sophisticated self-closing taps are also in use, but on a more limited scale. Among the various types are the fordilla valve, Aquatrol valve, Tylor "Waste Not" valve, and the Tropicale device. These are generally constructed using some form of piston or plunger which automatically shuts off the water after a liter or two has been dispensed.

A cheaper and less sophisticated flow-limiting device is a crank-operated water paddle wheel which has been used on public standposts in some areas of Nigeria and Cameroon. When properly maintained the device seems to function reasonably well; it does not dispense water except when the crank is being turned, is made locally, and takes a low level of skill to maintain and repair. The problem is that paddle wheel bearings tend to wear out, crank handles tend to be stolen, and if the wheel is not maintained regularly very little water can be dispensed. In areas where water pressure is low, or water supply intermittent, a hand-pump sitting on top of an underground reservoir or cistern has proven useful. Of course, another means of limiting water consumption is the conscious provision of intermittent water service to users. Although this could cut down on water production and storage costs, it also undoubtedly reduces the potential benefits of the system. People tend to use other water sources when the system is not operating, thereby negating much of the health benefits of the system. Finally, intermittent service in some instances actually increases water use because of an uncertainty about when the water will be turned on again.

The Willingness and Ability to Pay

To be a useful concept, willingness to pay has to assume an ability to

pay. The combination of low per capita incomes and higher per capita costs (for a given quality of service) in rural areas constitutes a formidable obstacle to improvement in the rural water supply field. Any rapid expansion of service to the rural poor requires that the willingness-to-pay criterion be modified to allow low-income groups to obtain at least a basic supply of water for minimum health needs. In practice, therefore, subsidy might be necessary.

We have observed that many different methods of charging for water are used in developing countries, but in most countries it is fairly clear that rural consumers normally pay less than average system costs, and frequently even fail to cover operation and maintenance costs. In fact, the WHO data presented in Table 1 show that, of those rural programs surveyed, well over half require only partial payment, or no payment at all, toward system operation and maintenance costs.

Table 1: Patterns of User Participation in Covering Costs of Urban and Rural Water Supply
(Numbers of countries)

	Operation maintenance and capital repayment	Operation maintenance and partial capital repayment	Operation and maintenance only	Partial operation and maintenance only	No payment
Urban Areas					
Africa	14	6	1	7	1
Latin America	14	10	8	9	0
Eastern Mediterranean	5	8	8	11	1
Algeria, Morocco, Turkey	0	1	2	0	1
Southeast Asia	2	2	3	3	0
Western Pacific	3	3	0	3	0
Totals	38	30	22	33	3
Rural Areas					
Africa	2	4	6	11	10
Latin America	3	9	7	11	4
Eastern Mediterranean	1	2	7	12	9
Algeria, Morocco, Turkey	0	0	1	0	2
Southeast Asia	0	2	2	3	5
Western Pacific	1	2	1	1	4
Totals	7	19	24	38	34

Source: World Health Organization, Statistics Report, Vol. 26, No. 11, 1973, p. 753.

Since the primary rationale for subsidization of rural water supply is the lack of the beneficiaries' ability to pay, two questions should be investigated: the average real income of the population, and the amount of that income that can be spent on water. Money income may be very different from real income in rural areas because of the prevalence of subsistence agricutlture. With little or no reliable data available on either money or real income in rural villages,

the estimation of the real income of rural populations is an extremely difficult task.

Even if the real income level was known there is the second question: What amount of a family's real income can be spent on water? A frequently used rule-of-thumb reply is that a rural near-subsistence family should never have to spend more than about 5 percent of its income for water. This 5 percent-of-income figure is usually more than most urban dwellers pay for the water they consume from the public system. Some tentative estimates of the percent of household income spent for water in twelve selected cities in developing countries indicate that the lowest income group pays about 5 percent of household income only in Sao Paulo and Lima, and 7 to 9 percent in Addis Ababa, Manila, and Nairobi. In the remaining seven cities the figure is much less than 5 percent. Reliance on an arbitrary 5 percent of income rule is fraught with hazards, especially in rural areas. Clearly, the "appropriate percentage" will be determined in large measure by the degree of monetization of the local economy, the cost of other essential items, and so on. Furthermore, who is to decide what the word "appropriate" means in each case?

Even if a villager can pay for water, he may not be willing to alter his current expenditure pattern, or reduce his slight savings each month, in order to improve the quantity or quality of his water. If so, there are two alternatives available to the water supply authorities once they have decided that the villager needs, and will be provided with, an improved water supply. They can attempt to alter the villager's perception of the value to him and his family of a better water supply, generally by some form of demonstration or education program acquainting the villager with the more obvious benefits of improved water and sanitation. If this education function is successful, the villager will then value the improved system more highly, and therefore be willing to pay a higher price for it. The second alternative is for the water supply authorities to subsidize the village system, using the rationale that the unrealized or unperceived benefits which accrue to the villagers, together with the benefits external to the villagers but which accrue to society as a whole, make the subsidy worthwhile.

A few countries, particularly in Latin America, have attempted to gather information on the ability to pay of village dwellers by undertaking so-called social, or socioeconomic, surveys of villages. Most surveys have consisted of little more than forms on which a casual observer documents his impressions of a village after visiting it for an hour or two, but several of the more elaborate surveys have contained a sometimes lengthy set of questions. Questionnaire approaches such as these almost always produce very low estimates of ability and willingness to pay. This result is not surprising, as

it amounts to approaching a group of individuals, strongly hinting that they are going to receive a certain good, and than asking if they would prefer to (or could) pay a high price or a low price for that good. Given these difficulties, we have particular doubts as to the practical relevance of the concept of ability to pay in arriving at a judgment about willingness to do so. There is much evidence that even where consumers are wealthy, they often refuse to pay or otherwise cause difficulties for a water authority which is attempting to introduce or increase water charges. This leads us to suggest that the only way in practice to address this issue is, rather than to conduct elaborate, assumptive socioeconomic surveys, to "test the market" by the gradual introduction of new tariff policies, and then to observe consumer reaction before deciding to increase those charges or to expand capacity.

The general lack of any hard evidence on ability (and willingness) to pay has resulted in the politically expedient assumption, which has been made in most developing countries, that the rural population cannot pay the full cost of water. As noted earlier, in a number of Asian and Latin American countries, the beneficiary village is expected to make only a partial contribution of between 10 and 30 percent to construction costs, and to pay only for the operation and maintenance of the system. Experience in these countries suggests that this is a minimum for program viability. In a few countries, such as Zambia and Tanzania, rural consumers do not pay at all.

The most prominent or frequently stated rule of thumb about an acceptable minimum a village should be required to pay to be eligible to receive an improved water supply system in the first place is that the village should at least be able to cover ongoing operation and maintenance expenses. This principle probably has administrative rationality in that it simplifies local accounting, and it bestows upon the villagers the psychological satisfaction of paying for what they can see is taking place. In addition, capital funds are relatively easy to budget, get grants for, and so on, whereas adequate funds for operation and maintenance tend to be more difficult to generate from central government sources. However, the distinction of capital costs from operating costs for purposes of subsidy can hardly affect the magnitude of the health and economic benefits the villagers receive from the project.

[Extracted from Chapter 7 of Village Water Supply: Economics and Policy in the Developing World. Baltimore and London: The Johns Hopkins University Press. Copyright © 1976, The International Bank for Reconstruction and Development.]

TROPICS

A JUNGLE CLEARING IN COLOMBIA
(PHOTO: THE WORLD BANK, BY EDWIN G. HUFFMAN)

The Tropics and Economic Development

Andrew M. Kamarck

[Countries located in the tropics seem to have an abundance of obstacles to overcome in their national development. This article traces the effects of tropical climates on agriculture and nutrition, as well as human health and mineral discovery, and indicates the kinds of research and solutions which can help to eliminate the worst effects of a tropical climate on economic development.]

The effects of tropical climate are not absolute obstacles to economic development, but they do make many of the problems of economic development in the Tropics sufficiently different from those in the Temperate Zone countries that an additional hurdle has to be overcome and, consequently, all other relevant factors being equal, the pace of development in tropical countries tends to be slower. By 1971, at the beginning of the Second Development Decade, almost all the countries in the North and South Temperate Zones of the world had succeeded in becoming either "rich" countries, with a per capita gross national product (GNP) of more than $1,000, or "middle-income" countries, with a $375 to $1,000 per capita GNP. On the other hand, most of the countries with a tropical climate were "poor"--with GNP per capita $100 to $375--or "very poor"--GNP per capita under $100.

Most recent economic writing on development has paid little or no attention to any possible influence of climate. Mathematical growth models make no provision for climatic parameters or variables. There is no mention of climate, for example, in the combined list of "characteristics of backward economies" devised

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by Harvey Leibenstein from various leading economic writers whom he surveyed for this purpose. Albert O. Hirschman, in summarizing theories that Latin Americans and others have presented to explain Latin America's lag in economic development, did not mention climate once. Part of this neglect of climate is probably a strong reaction against earlier theories of geographers, particularly that of Ellsworth Huntington who maintained that the different climates determined different levels of civilization through direct effects on human energies and achievement: human achievement is said to result from the degree to which the weather is moderate and variable. This argument is not very convincing. Nevertheless, the fact remains that no tropical country in modern times has achieved a high state of economic development. As I hope to show, economists were right to be dissatisfied with Huntington's theory, but wrong to assume that climatic factors should then be totally neglected.

There are a number of reasons why we need a more accurate diagnosis of the real problems of development in the Tropics. The first is fairly obvious: if we do not know what the obstacles are, we cannot pursue the proper policies to eliminate or to avoid them. The second reason for better understanding is to avoid the disillusionment and despair already setting in among many people over the prospects for development in the less developed countries. Without an appreciation for the magnitude of these difficulties, people soon suffer disappointment over the rate of progress in overcoming them. Finally, a proper understanding of the different and greater obstacles faced by the developing countries in the Tropics will help keep people in the richer countries from falling into the arrogant or racist conclusion that the developing countries are poor because their peoples are somehow inferior.

Here we will first attempt to outline major characteristics of the tropical climates that are significant to economic development. Next we consider the adverse effects of tropical climate on agriculture and the first systematic international effort to mobilize the knowledge necessary to cope with these effects. The next section briefly indicates how the tropical climate adversely influences exploration for mineral resources. The final section outlines the widespread extent of diseases in the Tropics that directly affect man's economic activity.

None of this is to claim that climate has a mechanical one-to-one relation to economic development, nor that it is the only ruling constraint on national progress. Yet, in today's poor countries climatic factors have demonstrably hampered economic development through their impact on agriculture--directly or through the diseases and pests afflicting animals and plants--on mineral discovery, and on man himself through disease. These effects need to be better understood. High priority should be given investment for research to find ways to minimize the adverse impacts of climate and to turn the particular manifestations of local climate to advantage.

As economic development proceeds in a country, it will become easier

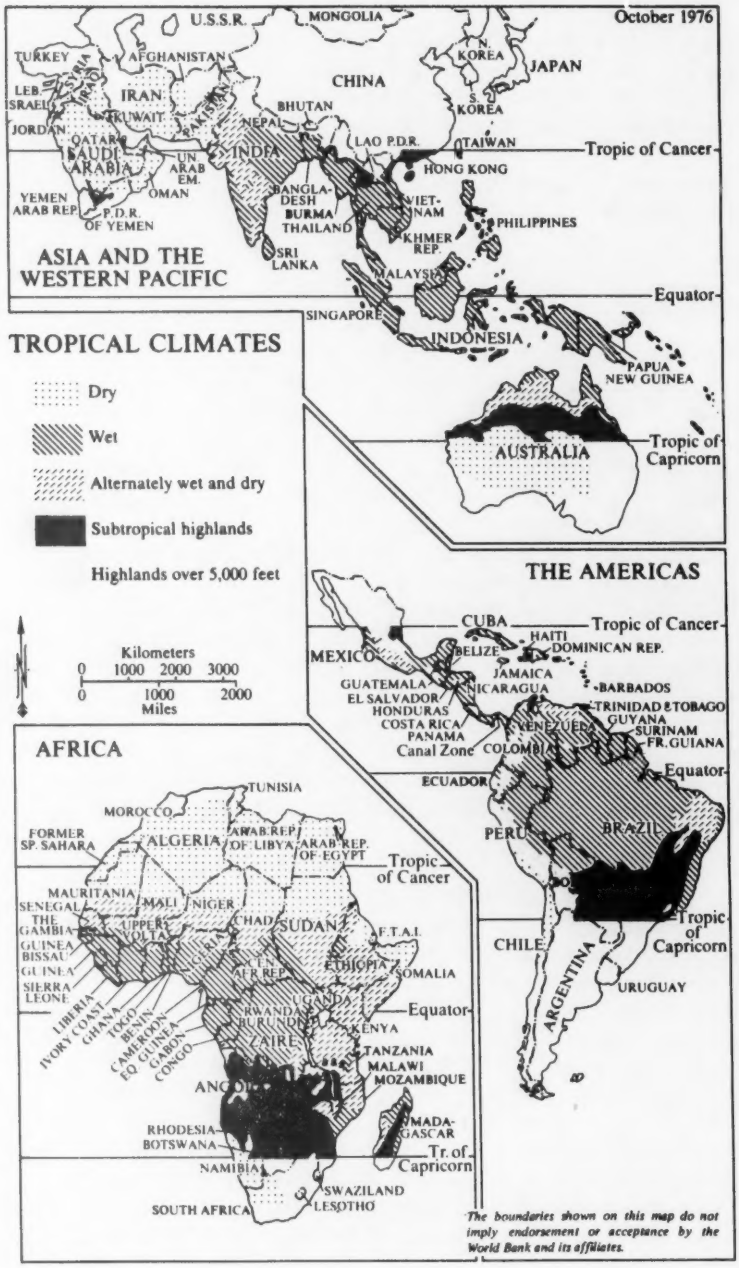
to eliminate or to avoid the worst effects of tropical climate, and climate will become less important as a factor in development. As individual incomes rise, a smaller and smaller proportion of income is spent on food. The proportion of GNP produced in agriculture will therefore tend to drop and, consequently, climatic factors affecting agriculture will become less important to national growth. The relative importance in the development process of possessing mineral resources also varies inversely with the level of development. Finally, growth in GNP enables greater expenditure on health problems, attenuating this impact of climate.

Climate in the Tropics

A tropical climate affects all of Africa except South Africa and portions of countries in the extreme north of the continent; all of South America except Argentina, Chile, and Uruguay; Central America and the Caribbean including southern Mexico; and south and southeast Asia. There are three principal types of tropical climates, as the map illustrates: wet equatorial, dry tropical, and alternately wet and dry tropical (monsoon). The wet equatorial, or humid, tropical climates lie mainly within 5° of the equator. In these latitudes some rain falls in all months, and usually totals 200 to 300 centimeters a year (roughly 75 to 120 inches). The wet equatorial climate is characterized by constant heat, rainfall, and humidity. The dry tropical climates are dominated by dry air masses descending and moving away from the subtropical high pressure cells over the large land masses. Hot, arid climates and desert areas result, where rainfed agriculture is practically impossible. Regions lying between the wet equatorial climate and the belts of dry tropical climate have alternately wet and dry tropical climates. These regions tend to have a wet season when the sun is overhead and a dry season when the sun is lower.

Rainfall and Heat. Rainfall rather than temperature determines the seasons in the Tropics. The variation of rainfall from year to year and within the year is considerable and unpredictable, and the average temperature in the coldest month is at least 18°C (64°F). Yet rainfall in the Tropics is usually too much or too little. Average annual rainfall means little when one year may receive three times as much rain as the next, or when it does not rain evenly throughout a given season of the year but falls in torrents within brief periods. The extremes are often almost absurd: in July 1972, 4.4 meters (14.5 feet) of rain fell on Luzon, on which much of the economic effort of the Philippines has been concentrated. The rice crop on 1 million acres was destroyed, as was 30 percent of the sugar crop which dominates Philippine export earnings. The impact of floods in Bangladesh, and of drought in the Sahel, are well known.

Rain is a preoccupation for most people throughout the Tropics. A remark by Washington Post reporter Jim Hoagland on Africa applies to most of the Tropics: "More than 85 percent of Africa's 300 million people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TAIWAN
Tropic of Cancer
HONG KONG
YEMEN ARAB REP.
P.D.R. OF YEMEN
OMAN
BANGLA-DESH
BURMA
THAILAND
VIET-NAM
PHILIPPINES
KHMER REP.
SRI LANKA
ASIA AND THE WESTERN PACIFIC
MALAYSIA
Equator
SINGAPORE
INDONESIA
PAPUA NEW GUINEA
AUSTRALIA
Tropic of Capricorn
TROPICAL CLIMATES
Dry
Wet
Alternately wet and dry
Subtropical highlands
Highlands over 5,000 feet
Kilometers
0 1000 2000 3000
0 1000 2000
Miles
THE AMERICAS
CUBA
Tropic of Cancer
HAITI
DOMINICAN REP.
MEXICO
BELIZE
JAMAICA
GUATEMALA
NICARAGUA
BARBADOS
EL SALVADOR
HONDURAS
TRINIDAD & TOBAGO
GUYANA
COSTA RICA
PANAMA
Canal Zone
VENEZUELA
SURINAM
COLOMBIA
FR. GUIANA
Equator
ECUADOR
PERU
BRAZIL
AFRICA
TUNISIA
MOROCCO
FORMER SP. SAHARA
ALGERIA
ARAB REP. OF LIBYA
ARAB REP. OF EGYPT
Tropic of Cancer
MAURITANIA
SENEGAL
MALI
NIGER
THE GAMBIA
UPPER VOLTA
CHAD
SUDAN
GUINEA BISSAU
GUINEA
F.T.A.I.
ETHIOPIA
SIERRA LEONE
C.A.R.
SOMALIA
LIBERIA
IVORY COAST
GHANA
TOGO
BENIN
UGANDA
RWANDA
BURUNDI
Equator
KENYA
CAMEROON
EQ. GUINEA
GABON
CONGO
ZAIRE
TANZANIA
MALAWI
MOZAMBIQUE
ANGOLA
MADA-GASCAR
RHODESIA
BOTSWANA
Tr. of Capricorn
NAMIBIA
SWAZILAND
LESOTHO
SOUTH AFRICA
CHILE
ARGENTINA
URUGUAY
Tropic of Capricorn
The boundaries shown on this map do not imply endorsement or acceptance by the World Bank and its affiliates.

eke out their livings as peasant farmers, and a failure of the rains to come can be a devastating economic disaster. If the question, 'How do Africans live?' means how do most of them spend the majority of their time, the answer probably is 'Thinking about rain.' Life tends to be organized around it, in the way that consumer goods are the centerpiece of Western societies."

Continuous heat and the absence of frost mean that life and reproduction go on throughout the year. The great executioner of nature, winter, is absent. No winter temperatures constrain continuous plant growth or the continuous reproduction and growth of all other kinds of life: weeds, insects, birds, parasitic fungi, spider mites, eelworms, microbes and all kinds of viruses--pests and parasites on man, his animals, and his crops. Life over most of the Tropics therefore takes on an infinite multiplicity of forms; fierce competition results, and only a relatively few individuals in every generation of any species survive in any one place. The conditions are ideal for rapid evolutionary change to adapt to any new opportunities.

Economic Implications. These central biological parameters of the Tropics have considerable economic implications. Because of the multiplicity of species and the rapid evolutionary potential of the Tropics, there is a high probability that any new plant or animal introduced into an area by man will soon be attacked by some rapidly multiplying enemy. A crop successfully established always runs the considerable risk of attracting some new pest that has suddenly appeared. For example: "coffee rust which eliminated the arabica coffee industry in Ceylon (Sri Lanka); blister blight of tea before control measures were found in Ceylon, South India and Indonesia; 'sudden death' in Zanzibar cloves; 'swollen shoot' in West Africa cocoa; 'wither-tip' of Dominican limes; and Panama disease of 'Gros Michel' bananas." The Tropics are littered with the ruins of development projects that refused to recognize these special problems. A British Colonial Development Corporation million-dollar chicken-raising scheme in The Gambia was completely wrecked by a disease that killed off chickens by the hundreds of thousands. The Richard Toll rice-growing scheme in Senegal has not yet learned to cope with the hundreds of thousands of weaverbirds (Quelea) that descend on the paddies each year when the rice is ripe. The Gezira Scheme in Sudan started with splendid crops, but after a few years "the virgin land...appeared to be worthless, filthy with weeds and foul with disease." Only the fact that the Gezira company recognized the critical importance of research in the Tropics kept the whole scheme from collapsing in disaster.

Consider two brief examples of some aspects of climate's impact on two areas, Africa and Brazil. Africa is preeminently tropical among the continents: over 75 percent of its 30 million square kilometers are in the Tropics. Only countries hugging the top of the continent and South Africa, Swaziland, and Lesotho on its southern tip escape a predominantly tropical climate. Climate has had a pervasive and continuing influence on Africa's development; in earlier centuries it isolated Africa from the rest of the world. Yellow fever and malaria levied a heavy toll of death on all

visitors to tropical Africa. Trypanosomiasis carried by the tsetse fly killed horses and cattle and made it impossible to get to the interior from the coast using animal transport. Commerce had to depend on human porters, the most costly and inefficient of all transport systems. Thus, aside from the other grave difficulties of the Tropics, the transport obstacle alone was quite sufficient to postpone for centuries any appreciable economic development in tropical Africa.

Southern Brazil has benefited from the higher altitudes of the interior that foster relatively cool climates, so that the highlands of southern Brazil are climatically similar to the eastern Appalachians of the United States. It is precisely in this more favorable climate that Brazil's economic development has reached a middle-income per capita level. The northeast of Brazil, on the other hand, the country's problem area with a population of around 30 million, is dominated by a wedge of tropical dry climate situated between a humid strip along the east coast and the tropical wet-and-dry savanna stretching north and west to the Amazon rain forest. Brazil's northeast is subject to random, recurrent droughts that may continue from one to three years. These droughts effectively bring development plans to a halt. Yet development approaches have heretofore tended to invest mainly in fixed capital of various kinds, rather than in necessary research to find out how best to handle the droughts. Over the last fifty years many dams have been built, but little use has been made of the water for irrigation, in part because of what Albert O. Hirschman characterizes as a lack of knowledge of the terrain and soils. Indeed, there may be some doubt whether irrigation makes sense at all: Hirschman noted that because of high evaporation in reservoirs it was necessary to collect all the rain falling on 100 hectares for a year to get enough water to irrigate 1 hectare. At the same time, most of northern Brazil--and the countries bordering Brazil in the north and west--are within the humid Tropics; these lands remain largely undeveloped and unpopulated.

Soils

Soil is inevitably the foundation of farming. A principal characteristic distinguishing tropical countries from rich and middle-income countries is their comparatively greater ignorance of how they might best exploit and improve their soil. In the main, the basic farming conditions related to the character of the soils in tropical countries are so different from those of the Temperate Zone countries that dealing with them requires building another body of knowledge altogether. That is one of the important facts about economic development in today's poor countries. Agriculture is the dominant economic sector in developing countries; yet these countries cannot simply follow the path trod by today's rich nations when they were poor, because the basic agricultural conditions in the less developed countries are significantly different. Not all tropical soils are equally problematic. But there are special problems in tropical agriculture that are major obstacles to economic growth, and they need to be specifically recognized as such. These

obstacles may not be insuperable; with sufficient research they may be overcome or bypassed.

Good soil is much like a complex living organism. Its skeleton is made up of numerous tiny mineral soil particles aggregated into a firm and flexible structure. Intermingled with this skeleton is the organic substance, the humus, that is the product of bacteria action on plant litter. In less than half a kilogram of fertile soil there may be 500 million fungi, 500 million protozoa, 10 billion bacteria, and 400 billion algae. Aside from their general function of creating humus, these organisms often perform specific and essential functions. For example, the successful establishment of the rapidly growing North American Monterey pine (Pinus radiata) in forestry plantations in eastern Africa depended on cultivating not only the seed but also the particular fungus with which the tree roots have a close cooperative relation.

For all these organisms to exist, the soil structure must be such that it can obtain freely circulating air and water. In the Tropics, the soil has to be protected against the heat of the sun, which would burn away the organic matter and kill the microorganisms. It also has to be protected from the direct blows of the torrential rains, which would crush the structure of the soil, seal off the underlying soil from the air, and leach out the minerals or carry them so far into the earth that the plant roots could not reach them. When protective tree cover is removed and the soil is laid bare and exposed to the elements, its temperature rises and the sun hastens the oxidation and disappearance of the humus. Wide variation in temperature occurring in the Tropics between day and night accelerates the mechanical disintegration of the soil. Finally, rains and wind erode the soil.

Generally soils, except where there are alluvial or recent volcanic soils, are poor over most of the Tropics because they contain little organic material. Tropical vegetation often looks rich and luxuriant, but appearances are deceiving. Even in dense forests, soils are usually thin and have low fertility. In these forests, decaying plants and trees constantly return to the supporting soil the elements they borrowed from it. An equilibrium is maintained--a precarious one, with very small reserves.

In monsoon climates, the one- to three-month period before the rains break is the driest and hottest time of the year. This makes the farmers' preparation of the dry, hard ground for planting particularly arduous. By comparison, temperate climates experience cold weather precipitation that exceeds evaporation; the soil in those regions therefore becomes charged with a reserve of water for the new growing season. Moist soil is easier to work. In tropical Africa, the pattern of rainfall and the relation between precipitation and rates of evaporation also result in frequent drought or flood. Productive periods must be sandwiched between these droughts and floods. Consequently, proper soil and water management and careful timing of farm operations are vital in Africa. The different water regimes of Africa also require different approaches to such things as the application of fertilizers and different techniques of plant protection.

Over a very large part of the humid Tropics the soil has turned into laterite. Through leaching, the main plant foods or assimiliable bases and phosphorus have been removed from the top layers of the earth. What is left is a reddish mottled clay, consisting almost entirely of oxides of iron and hydroxide of aluminum that tend to solidify upon exposure to air. While laterite makes useful building material, these so-called tropical red and yellow earths that cover the greater part of the humid Tropics are either agriculturally poor or virtually useless. This soil composition accounts for some of the large iron ore deposits in the Tropics, especially in the Philippines and Rhodesia, and explains the large bauxite deposits mined in tropical countries for the aluminum industry. The distribution of laterites throughout the world is quite similar to that of humid tropical areas as shown on the preceding map.

Over the centuries, the inhabitants of many such areas established a method of cultivation to meet the soil conditions confronting them. Shifting tillage, still by far the most common type of agriculture in use in the humid tropics, cultivates fields for one or a few years, then allows them to revert to bush jungle to restore their fertility over periods lasting at least several and sometimes as long as twenty-five years. Shifting cultivation makes survival possible under difficult conditions--but at a bare existence level.

There are two important exceptions to the rule of poor soils in tropical countries. Alluvial soils are fertile, and may be found along lakes, in river valleys, and in deltas. Recent volcanic soils are also usually fertile. Less extensive, but worthy of mention, forest soils of tropical mountains that are high enough to escape the great heat of lower altitudes may be fertile and rich in humus. South and southeast Asia are more favored with alluvial soils than any other major area with a tropical climate. The great rivers in this area bring down much of the soluble plant food that has been removed from the soils upstream in the catchment area. Some areas in south and southeast Asia, however, notably the coastal plains in parts of Sumatra, Borneo and New Guinea, suffer the drawbacks of vast swamps: waterlogged soil inhibits bacterial action and dead vegetation accumulates at the surface. Elsewhere, in large areas of Indonesia plus scattered parts of the Philippines and the Deccan plateau in India, the soil has been formed from volcanic eruptions and this too may be very rich. Tropical Africa's largest areas of alluvial soil are in Uganda and between the Blue and White Nile in Sudan. Volcanic soils are found in Rwanda, Burundi, western Cameroon, Ethiopia and in central Kenya and Tanzania. In the Americas, fertile volcanic soil is present on some of the Caribbean islands and in parts of Mexico, Costa Rica, and Colombia.

Protein Supply. The composition of soils over most of the Tropics affects the character of the food supply grown. The chemical makeup of tropical soils tends to result in a shortage of protein in the diet--a nutritional shortage that has an impact on work efficiency. As might be expected, tropical plants tend to be poor in nitrogeneous constituents

which must be manufactured from the precarious supplies in the soil. On the other hand they are relatively rich in carbohydrate which can be synthesized by the plant from carbon dioxide in the air and the abundant water. Sugar, manioc, rice, sweet potatoes, bananas and plantains are familiar examples of tropical foodstuffs rich in carbohydrate but relatively poor in protein.

Protein is the critical nutrient for human physical and mental growth, and its shortage may be a major factor inhibiting development. Considerable evidence further indicates some relation between malnutrition of children, mainly protein shortages, and mental retardation. The chain of evidence is still quite fragile, but it does appear possible that the peculiar composition of tropical soils has had a substantial impact on the pace of development in passing along a nutritional deficiency to humans.

Agricultural Enemies

Any attempt to introduce or expand the output of a particular crop increases the dangers associated with species of insects and other forms of life that prey on it. Not only does such introduction or expansion run the risk of rapid multiplication among the wide variety of existing predators, but it may also encourage the activation or evolution of a new set of predators. In addition, animal diseases constitute one of the most important limitations to the development of more productive livestock industries. The greatest total loss results not from the spectacular epidemic diseases but from the many parasitic, infectious, nutritional, toxic, metabolic, and organic diseases that affect livestock. Although many principles of medical science and disease control developed for temperate regions apply to tropical problems, there is a critical deficiency in knowledge of tropical veterinary medicine.

That same tropical environment that favors the rapid and luxuriant growth of crops and vegetation also nourishes those weeds that compete for moisture and nutrients. Gordon Wrigley, in his standard work on Tropical Agriculture: The Development of Production, also notes that without a "closed season" for plant growth, all sorts of pests may thrive all the year: not only weeds, but the parasitic fungi, insects, spider mites, eelworms and virus diseases that make for serious reductions in the crops. After harvest, serious losses can result from storage pests and rats.

Some enemies may largely wipe out a crop, while others that are not lethal to the plant but just as insidious may cause crop damage. For example, Wrigley mentions the loss of rice in Asia from stem borers and "blast". According to 1954 estimates in the British colonies, the loss of crops from fungal disease alone totaled 12 percent of all crops, varying from over 25 percent of the beverage, drug, and spice crops to about 5 percent of the fruits and pulses. Wrigley concludes that, if

weeds, insects, and storage pests all take similar tolls, half the potential harvest is being lost. Researchers estimate that the cost of insect control is around 20 percent of the value of the cotton crop in Colombia and about 45 percent in Nicaragua. To this would also need to be added the losses due to weeds and any diseases of cotton.

Locusts. Gigantic swarms of desert locusts can fly over 1,900 kilometers nonstop and attack crops anywhere from west Africa through to India. The red locust by comparison is limited to southern, central, and eastern Africa. Effective action against either species of locust requires international cooperation. [See Development Digest, January 1969, pp. 77-94.] The red locust has been successfully controlled in this way in recent years--the desert locust only partially. But in both cases, control has relied too much on insecticides and now the locusts show signs of growing resistance.

Trypanosomiasis is one of the most important obstacles to economic development in Africa. The disease is caused by trypanosomes (a protozoan flagellate), principally carried by the tsetse fly, and takes many forms including nagana, sleeping sickness, and Chagas' disease. African forms of trypanosomiasis are serious diseases. Most are transmitted through the actual bite of an infected tsetse, which in sucking blood introduces the parasitic trypanosome into the blood. In humans, the parasite eventually enters the nervous system and affects the brain and spinal cord. Unless treatment is obtained, the infected person dies after a period of lethargy. Drugs are now available that can effect a cure, and in some but not all cases innoculation will give temporary protection against infection. Repeated surveys, constant surveillance with mass treatment, and avoidance of some areas for settlement, have reduced the incidence of human sleeping sickness to a fairly low level. The mortality rate has been greatly reduced.

Cattle, if only lightly infected by the parasite, can be treated with drugs and cured. However, in vast areas eradication of the disease has not yet proven possible, and the density of flies and the disease make the drug treatment for cattle ineffective. The animal disease has its natural reservoir in the wild animals of Africa, who have built up an immunity to it. Over the larger part of tropical Africa, the fly and its transmission of a trypanosomiasis called nagana has prevented the keeping of cattle for food or for use as draught animals. Over 10 million square kilometers of Africa--an area greater than that of the United States--are thereby denied to cattle. There are now around 114 million cattle in Africa. If the carrying capacity of the infested area be taken at about 12 cattle per square kilometer (1 every eight hectares, or the present average carrying capacity of land in Africa) the land cleared of the fly could carry an additional 128 million cattle: cattle output could be roughly doubled. Since the main food deficiency in Africa is protein, the increased meat supply could also have substantial indirect productive benefits. The ability to use draught cattle in most African farming areas would also mean that cultivation no longer would be limited by dependence on human muscles, and that mixed farming with the use of manure for fertilizer would finally be practicable in most areas.

In the Sahara and adjoining semidesert zones, where humidity is low and there is little shade, the tsetse survives only in the fringe forests along river banks. Closer to the equator, where acacia and similar trees provide shelter, and in the humid tropical forest zone, the fly can often take over completely. If human population is sufficiently dense to destroy the tree shelter for the fly, the tsetse may be pushed back and trypanosomiasis may be controlled by drugs. Unfortunately, because of the poverty of African tropical soils, shifting cultivation may be necessary. Allowing cultivated areas to revert to bush fallow to restore fertility recreates a natural habitat for the fly.

The history of efforts to combat the fly is one of constantly fluctuating battle lines. Three main approaches have been to destroy the breeding areas of the fly by clearing the type of bush it favors; to remove its food supply, shooting out all the game; and to kill the fly with insecticide. When the fly is destroyed in an area, an attempt is made to maintain a fly-free barrier against still infested areas. But the fly has shown considerable ingenuity in surviving: it has developed a fondness for traveling by automobile, and unless automobiles coming out of infested areas are cleaned of the fly it may leapfrog control measures directed against it.

The American form of trypanosomiasis occurs widely throughout South America but is much less important than the African disease. It is usually known as Chagas' disease and results in anemia, swellings, fever, and heart disease. It is transmitted mainly by a species of bed bug and, consequently, Chagas' disease can be prevented by domestic sanitation.

Agricultural Research

The difference between the set of parameters confronting agriculture in the Tropics and the set in the Temperate Zone is not economically trivial: so far the difference has helped keep people in the Tropics poor. But this may be true largely because existing agricultural technology was developed mainly to handle the problems and characteristics of Temperate Zone agriculture. Some characteristics of the Tropics give tropical agriculture potential advantages over that in the Temperate Zone. Sunlight energy for plant growth in the humid Tropics ranges between 60 and 90 percent higher than that available in humid temperate regions. Plants in tropical rain forests produce as much as three to five times more organic matter each year than do plants in temperate forests. Once pests are controlled, the absence of winter can extend the length of the growing season. The multiplicity of species could help in developing new and better crops and livestock.

In the field of livestock, a principal technical reason for low levels of productivity stems directly from the tropical climate itself. Low productivity is due mainly to the wide seasonal fluctuations in the growth

and quality of pastureland, caused by the alternating wet and dry seasons in large parts of the Tropics. Because these areas lack stock watering facilities, the number of animals that can be safely carried through the dry season is the maximum that can be carried for the whole year. Moreover, much of the weight that the livestock gain during the wet season when feed is plentiful is lost when feed is short, so the average yearly weight gain is very low. Long periods of underfeeding lower the reproduction rates of the herd, and increase susceptibility to parasitic and other diseases. By providing fences, water, and corrals, which are essential both for grazing management and controlling disease, it is possible to achieve triple and even greater increases in production. In addition, pastures can be improved by using a number of new legume plants that fix nitrogen in the soil and that have been developed for the tropical areas of Australia in Queensland.

The emerging theme in crop agriculture is the need for research into means of coping with tropical obstacles while turning some tropical characteristics into assets. Today's comparatively advanced state of agriculture in the Temperate Zones took many years to achieve. Until very recently, however, there has been little research on tropical agricultural problems other than on some export crops and, more recently, on tropical wheat and rice. Since World War II experiments with fertilizer, and plant breeding in tree crops such as rubber and palm oil, have produced remarkably good results in productivity and improved plants. But fertilizers are expensive, and little is known about which specific soil deficiencies need to be corrected or how they can be best corrected. It took some twenty years, for example, to discover what essential trace elements (tiny percentages of, for example, zinc, boron, copper, and cobalt) had to be added to African pasture soils and what other adaptations to African conditions were needed to raise non-African breeds of livestock successfully.

Research in East Africa has shown that, in some circumstances, shifting cultivation can be modified by replacing the bush fallow with a grass that can be grazed by livestock as a productive part of land rotation. This makes it possible to maintain soil fertility without using fertilizers. One ingenious way governments have found to cut losses from pests is to impose an artificial winter. Many cotton-growing countries in the Tropics and sub-Tropics legislate a dead season by setting a date when the crop must be uprooted and burned and setting a date when planting may begin.

Over the last seventy years a combination of techniques has been developed to improve agricultural productivity in the temperate climates. In brief, biological engineering has learned how to create new varieties of plants tailored to a set of planned characteristics, adapted to take advantage of favorable climatic and soil characteristics and avoid unfavorable ones. The plants are bred to convert large amounts of fertilizer into a usable product rather than to excessive foliage. Pesticides for particular purposes are used, and resistance to pests and diseases may be bred into plants. This "package of techniques" approach has

evolved slowly in the industrialized countries and, until recently, it was not applied to the tropical countries. The experience of the Rockefeller Foundation in developing the high-yield Mexican dwarf wheat, and that of the International Rice Research Institute in developing high-yield rice, have shown that the 'package' approach to tropical agriculture can promote yields in the Tropics at least as high as those in temperate climates. The average yield of a commodity can be rapidly increased through application of a complete package of high-yielding varieties; appropriate fertilizer appropriately used; adequate disease and pest control; proper planting, cultivation, and irrigation techniques; and in the case of animals, the right breed, nutrition, and management. Such a "package of techniques" could offset the poverty of tropical soils through fertilizer, and offset erratic rainfall through irrigation and drainage; and it can take advantage of the heat and absence of frost to produce two or three crops a year.

New Research Organizations. An important step forward was taken in 1971 with the formation of the Consultative Group on International Agricultural Research (CGIAR), jointly sponsored by the Food and Agriculture Organization of the United Nations (FAO), the World Bank, and the United Nations Development Programme (UNDP). The Consultative Group establishes priorities for an expanded international agricultural research program on problems of the less developed countries and mobilizes and coordinates financial support for such a program. Its financial resources have grown rapidly, from $15 million at the beginning in 1971 to $64 million in 1976, and are obtained from an increasing number of donor countries.

The Consultative Group's main objectives include examination of the needs of developing countries for special effort in agricultural research on food crops. CGIAR works on international and regional levels in critical subjects otherwise not likely to be adequately covered by existing research facilities. It provides support for the following international centers: The Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) in Mexico has the responsibility for increasing the quantity and quality of maize and wheat production, and has made an advance of great importance in developing high-yield varieties of these crops. The International Rice Research Institute (IRRI) in the Philippines has the primary responsibility for research to increase the quantity and quality of rice production. IRRI's development of high-yield varieties of rice is well known. The International Potato Center (CIP) in Peru completed its physical plant and basic staffing in 1974. CIP has made useful progress in screening and adding to its collection of genetic material, and has identified potato varieties which may enable the Center to breed strains highly resistant to blight, the most destructive disease of potatoes in all latitudes. Four other centers, the International Institute of Tropical Agriculture (IITA) in Nigeria, Centro Internacional de Agricultura Tropical (CIAT) in Colombia, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India, and the International Center for Agricultural Research in Dry Areas (ICARDA) in Lebanon, Iran, and

Syria, are all "comprehensive" institutes. Each directs its research not only to the improvement of specific lines of agricultural production, with emphasis on its own region, but also to the improvement of systems of agricultural production--for example, crop rotation, cropping patterns, cultivation practices, and market relations. [For earlier articles on these and related subjects, see Development Digest July 1971, pp. 3-42 and October 1975, pp. 3-44.]

The international research effort is important, but it will not by itself be enough. Individual countries and different regions must apply the results, and this will necessitate local adaptive research. Research tends to be underrated in developing countries. Money spent on research is not as politically attractive as money spent on buildings or prestige projects. Economic planners neglect research because in conventional national accounting it is not regarded as "investment." International aid agencies have not generally given high priority to support of research in recipient countries, although this is changing. For example, there has been increasing inclusion of provisions for particular applied agricultural research in recent World Bank agricultural projects.

While the international community still has a long way to go in finding the most effective ways of meeting the problems of agriculture in the Tropics, at least now, in 1976, one can be confident that we are beginning to know much better how to identify the real problems and that we are better organized to find answers.

Minerals

One of the most effective ways in which a poor country can rapidly increase its foreign exchange earnings, government revenues, and investment is through the discovery and exploitation of some rich mineral resource. There does not appear to be any rational basis for supposing that countries in the Tropics should have poorer or fewer mineral resources than countries in the Temperate Zones. However, a relatively small portion of the world's nonfuel mineral resources has in fact been found so far in the tropical countries. This results primarily from the greater intensity of exploration in the industrial countries where scientific expertise is found; and when mineral companies undertake foreign exploration, they tend to go into other more deved oped countries. Reasons for a low priority given the search for these minerals in the developing countries, as summarized by Claude Isbister, are the following: First, the big investors have preferred to operate under what they consider stable governments and laws. Second, the economically developed countries tend to be in Temperate Zones where rock formations are well exposed, and it is only in the past twenty or twenty-five years that prospecting techniques have advanced from surface probing to coping with the third dimension of depth. Many of the developing countries are in tropical and subtropical areas of the world where mineral formations are overburdened by soil.

According to a World Bank study (Table 1), the developed market economies have discovered almost twice the value of nonfuel mineral reserves as the developing countries in relation to their area. (This is not true of petroleum, for which the search has been more intense.) The table shows the distribution of population, land area, and mineral reserves for developing and developed market countries and the centrally planned economies. Values of estimated mineral reserves are given as weighted averages of all those minerals with reserves (valued at the commonly accepted point of transfer) of more than $1,000 million.

Table 1: Distribution of World Totals
(percentages)

Region	Area	Value of estimated mineral reserves	Population
Developing market	49	38	50
Developed market	26	35	19
Centrally planned	25	27	31
Total	100	100	100

Estimates of reserves have well-known problems connected with them. For a mineral deposit to be classified as a reserve it must be economically exploitable, which may depend on changes in prices, taxation, and technology. Companies usually "prove" only sufficient reserves for the medium term; mineral discoveries are not immediately announced; and "strategic" mineral reserves are often kept confidential, as is also much information on mineral reserves in countries with centrally planned economies. Figures on reserves are therefore only indicative, but they do suggest that in this sector, as in agriculture, the less developed countries are confronted with greater difficulties in getting economic development going than the presently industrialized countries had.

The technical problems of finding minerals in the Tropics as compared to the Temperate Zones have been discussed by the U.S. Geological Survey. First, the geophysical and geochemical techniques available for securing knowledge about the basic geology of areas were for the most part developed and tested for conditions in the Temperate Zones. But the physical and chemical parameters of the humid Tropics are different, so conventional prospecting techniques and the interpretation of the data secured consequently need a different structure of reference. Even the instruments used may have to be different since extremes of heat and moisture quickly ruin much of the sensitive instrumentation available today. Base-metal deposits in temperate, semiarid, and arid zones are far more easily located than in the humid Tropics, where rains and high temperatures cause rapid weathering--the formation of laterite and other soil mantles that effectively hide the underlying rocks. Also, minerals

such as dolomite, limestone, gypsum, and salts of potassium and sodium are relatively soluble and are most difficult to locate in high rainfall areas. Consequently most of the mineral deposits that are found and exploited are these surface concentrations formed from the weathering action of the climate--for example, bauxite, some iron ores, manganese and nickel, tin, and diamond placers--which are easier to discover. While in some of the arid Tropics the problems may be no different from those of the arid Temperate Zones, the U. S. Geological Survey concludes that: "One of the most intractable problems faced in mineral exploration is posed by areas formerly possessed of a humid tropic climate but now through climatic change brought to an arid regime. Countries along the southern edge of the Sahara present classic examples of the conditions."

It was not until very recently that the international community recognized a need for special help to the less developed countries in their exploration for minerals. In December 1973 a UN Revolving Fund for Natural Resources Exploration was created to offer such assistance. In June 1975, the UN Development Programme agreed on the operational shape of the new fund and appointed a director. Organization and money-raising are proceeding, with initial resources of $5 million; another $5 million is in sight for 1977. If successfully launched, this will be the potential center for action to develop knowledge, techniques, and instruments that can be adapted to the problems of finding mineral resources in the Tropics. It is a useful beginning in coping with this important problem of the tropical countries.

Health Hazards

Recent economic literature reflects an amazing lack of consideration of the impact of disease on economic development. It is probably justified for economists working on problems of the more developed countries to ignore the economic impact of human disease: it can be assumed that the "average economic man" is in full command of his body and mind and that sickness, though not insignificant, is not normally a major factor in the growth and functioning of the economy. But this assumption is false in today's less developed countries in the Tropics. Lack of good health affects a person's attitude toward work, initiative, creativity, learning ability, energy, and capacity for heavy or sustained work or thought. In the less developed countries a person who has not been or is not being substantially affected by poor health is probably the exception.

It is possible that, in addition to sustaining an environment favorable to disease, the tropical climates also have a direct adverse impact on work efficiency, creativity, and initiative of humans and so, in this respect, are still another handicap to the economic growth of the less developed countries. In his pioneering work, D. H. K. Lee suggests that loss of mental initiative is probably the most important single direct result of exposure to tropical environment. Basically, the problem with this subject is that there

has been very little research on it, and what there has been done is mostly on people in temperate climates working under hot conditions. Even casual observation shows that productivity may suffer when a person feels too hot--or too cold. What has not been demonstrated is that economic activity (outside of agriculture) in hot climates where air-conditioning is now regarded as necessary for best productivity is handicapped as compared to activity in temperate climates where heating is necessary in winter. But agriculture is not air-conditioned and in most developing countries agriculture is the predominant economic sector. If tropical climates as such do adversely affect human productivity, initiative, and creativity, then this would slow down the pace of economic growth in the tropical countries.

A large number of factors influence the health of a population. Over the developing countries as a whole, the most important causes of poor health undoubtedly, to my mind, stem from the prevailing poverty. Except in a few instances--perhaps river blindness in areas of western Africa--the argument cannot be made that the tropical climate is the decisive factor in this reinforcing relation between disease and poverty. But there is sufficient evidence that tropical climates make the problem of sickness sufficiently more difficult to handle to warrant the conclusion that less developed countries in the Tropics have a harder task in this regard than countries in the Temperate Zones.

The difference in average life expectancy at birth in the less developed countries, 49 years, and in the industrialized countries, 70.4 years, indicates the differences in health conditions between the two areas. But it does not sufficiently bring home the fact that the population in the developing countries typically have to adjust to living with disease. To illustrate: in Colombia, 89 percent of the individuals sampled in an intensive nutritional study were infested with some form of parasites; in Peru only 9 out of 122 men sampled in the armed forces had no parasitic infection; autopsy records in some areas of east Africa indicate that more than 90 percent of the persons examined were harboring beef tapeworms. Schistosomiasis is the dominant infection in Africa affecting nearly half the population. A study of six villages in the northeast of Brazil found the average person harbored two species of parasitic diseases, and the hemoglobin content of his blood was less than half of what is medically regarded as normal. Similar results have been found for population samples in Tanzania, Indonesia, Sri Lanka, Bangladesh and Venezuela.

The greater incidence of disease in tropical compared to temperate climates stems from three basic sets of circumstances. First, tropical countries are subject to the diseases of the Temperate Zones and have in addition some diseases that the temperate countries do not. Next, the Tropics offer more hospitable conditions for some diseases than do the Temperate Zones: for example, most vector-borne diseases are easier to control in the Temperate Zones because winter kills the vector. Last, in some diseases, infected human beings can continue to function

more effectively in a cool climate than in the Tropics. This is true of some cases of trichinosis and of amoebic dysentery. Yaws, a disease caused by a spirochete, heals by itself when the patient leaves a hot and humid climate for a dry and cool environment. The pattern of causes of deaths roughly indicates important differences. Infectious, parasitic, and respiratory diseases account for around 44 percent of the deaths in the developing countries but only 11 percent in the developed countries.

In the short run, improved health is generally thought to result in an increased supply of labor, through increased time at work and productivity of the individual, and therefore in increased income. Even greater benefits of improved health may come in the long run and through the improvement of the health of the group or community. Improvement in one individual's health may have little measurable effect on production in agriculture, for example, because the existing organization modes and technology were set up within a framework of existing constraints, including the ill health of most farm laborers. A factory offers an even better example when the pace of the whole production process has been set to adapt to the poor health of the majority of the workers. As Carl Stevens says: "It is reasonable to suppose that . . . ill health exacts its greatest toll on productivity [by] contributing importantly to the failure to adopt otherwise available innovations, both technical and organizational, which have a far greater impact on productivity than that to be had from labor augmentation in the context of the traditional techniques." In the case of agriculture, farmers in poor health may well have insufficient physical energy both to do their traditional tasks and to invest labor time in improved technologies which may, for example, require increased weeding or double cropping if they are to succeed. Similar considerations apply to nonagricultural pursuits. Sick children do not learn well in school. If students are sick, the resources allocated to education are partly wasted and schools do not produce individuals with as high a level of basic skills as they would with healthier students. The labor force is less efficient for all these reasons. Further, economic development does not mean only increase in personal incomes; incomes are a proxy for individual well-being. While not quantifiable as easily as money incomes, good health may be regarded as an important component of real income.

Among the major diseases influencing mortality patterns and affecting the productivity of people are bilharzia, malaria, river blindness, and a host of parasitic diseases such as leishmaniasis, hookworm and other intestinal worms. Others found chiefly in the tropics and imperfectly controlled are cholera, yellow fever, and leprosy.

Health Research. Developing countries spend comparatively little on research when current curative and preventative needs are so overpowering. Of the $300 million spent annually by international agencies and bilateral donors for health projects in less developed countries, it is doubtful if more than $30 million is spent on research. By comparison, annual

expenditures on cancer research alone in all of the developed countries are around $1 billion a year. It was only in 1975 that the World Health Organization began to establish a research center in Africa to work on tropical diseases and to encourage the formation of a network of institutes, clinics, and field hospitals working on tropical diseases.

One of the reasons for neglect of the impact of disease is the natural carrying-over to the less developed countries of the usual unformulated assumptions with which economists from the developed countries operate, as noted earlier. Further, most economists visiting or working in tropical countries do so at a level of comfort and health protection that is not available to the mass of peoples in the Tropics. Similar high levels of health protection are generally at the command of a tiny governmental and economic elite in the developing countries themselves, and local development economists and planners tend to be a part of this elite. Economists are not alone in this insensitivity to the real health position--most medical schools, teachers, and doctors in the developing countries are also part of this privileged elite. These doctors are usually preoccupied with the medical problems that are the concern of the medical school teachers and doctors in the more developed countries where many of them got their training. They worry about degenerative diseases such as cancer and heart disease rather than the infectious, parasitic diseases from which the majority of the population suffer. And, in fact, the doctors in the developing countries are often concerned with such diseases because these are the diseases of their elite patients. In a typical developing country the bulk of the doctors practice in the capital city.

In 1881, de Lesseps, the promoter of the Suez Canal, failed in the attempt to build a canal across the Isthmus of Panama, defeated by malaria and yellow fever. In 1904-14, the U.S. Army engineers succeeded in building the canal because research had found the cause and the vector of these diseases. The United States began the construction by first undertaking an expensive and widespread program of sanitation to eradicate the disease-carrying mosquitoes. The prerequisite for success was, in other words, preliminary investment in public health. Since then, most large construction projects in the Tropics have been careful to take steps to protect their workers against the local diseases. But such measures are not taken for the bulk of the economy and the vast majority of the population.

When the present industrialized countries were still poor, there was greater recognition of the importance of disease prevention and public health as a factor in economic development. Essentially, the first substantial progress in health in the industrialized countries in the last century came through purification of water supplies and sanitary disposition of fecal waste. Then, further progress was made through the various research discoveries of the germ causes of disease and control of the insect vectors. In today's developing countries, the sheer obtrusiveness of disease has led governments to try to do something about it. But

because economists have refused to recognize the significance of the prevalent diseases for development, little attention has been paid to economic factors in allocating resources to disease control compared with other uses, or in securing maximum economic benefit from what resources were made available. The fact that much of the medical attention in developing countries has been concentrated on curative medicine for the elite rather than preventive medicine for the vast majority does not indicate that development objectives were being efficiently pursued.

Conclusions

This article has explored special constraints affecting economic development in the Tropics that are additional to those now faced by countries in the Temperate Zones. Whether in a particular case the tropical constraints are the ruling ones at the moment does not matter in this analysis. Sooner or later they will become important as other constraints are removed or disappear. Whether this makes the development threshold higher for tropical countries than that faced by the Temperate Zone countries that first began modern economic growth is not an important question today. What matters today is that there is a group of tropical countries that have a set of constraints on their development which cannot be handled by an easy transfer or adaptation of existing technology from the developed Temperate Zone countries.

Special measures, particularly in research, have to be taken to find ways of overcoming the special obstacles posed by the Tropics. In recent years the international development community has made a promising beginning in this. It is quite possible that when the tropical constraints are eventually mastered, characteristics that now hinder the Tropics may then give them advantages over the Temperate Zones. This may especially prove true in agriculture: as pests, predators, and diseases are controlled, the heat, sunlight, the almost infinite variety of tropical life, and the more rapid evolution characteristics of the Tropics should make tropical agriculture more productive than that of the Temperate Zones. In livestock, there is already beginning to exist a sufficient stock of knowledge to make this forecast credible.

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EXCHANGE RATES

COINS FROM A VARIETY OF COUNTRIES INCLUDING INDIA, RWANDA, ZAIRE, HONG KONG, ETHIOPIA. (PHOTO BY BRAATEN PHOTOGRAPHY, COURTESY COIN DEPARTMENT OF WOODWARD AND LOTHROP INC., WASHINGTON D. C.)

Flexible Exchange Rates and the Developing Countries

William R. Cline

[The effects of flexible exchange rates among major currencies on the developing countries is examined. It is concluded that the floating exchange rates since early 1973 have not had the adverse results which had been widely feared, and that on balance they could be regarded as beneficial.]

A crucial element in international monetary reform is improvement in the balance of payments adjustment process. There is widespread agreement that this improvement requires more flexible exchange rates than under the Bretton Woods system, and the Jamaica agreement of January 1976 legitimizes flexible rates. Yet there have been objections that greater exchange rate flexibility will be detrimental to the less developed countries (LDCs), as well as claims that these LDCs have already been injured by the Smithsonian realignment of exchange rates in December 1971, the February 1973 dollar devaluation, and the floating exchange rates of major currencies thereafter. This article first examines the attitudes of LDCs toward exchange rate flexibility and the logical arguments concerning the differential impact of flexibility on LDCs; it then reviews the empirical evidence on effects experienced by LDCs to date. The objective of this examination is to determine how the interests of the LDCs are likely to be affected by flexibility, and whether they should be accorded special treatment in a reformed monetary system.

Actual experience with floating rates since 1973 does not provide an ideal test of the impact on LDCs of a

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planned floating rate system. Floating exchange rates have existed by default rather than design. Monetary authorities have generally agreed that recent disturbances caused by the oil price rise, rampant inflation, and volatile flows of short-term capital ruled out the fixing of exchange rates. Parities set under these unstable conditions would very probably prove to be unsustainable. Nevertheless, a dominant official viewpoint (although not one shared by the United States) is that the experience of 1973 and after showed that allowing exchange rates to float in response to market forces is unsatisfactory. According to this view, trade values initially respond slowly or even perversely to exchange rate moves, so that floating could bring greater exchange rate swings than are justified for equilibrium over the medium and longer terms. However, the official goal of fixed rates with more frequent parity changes has been challenged on grounds that it would lead once again to massive reserve movements as governments attempted to hold their currencies, even temporarily, to agreed exchange rate relationships with each other. Of course, flexible rates do not at present float freely but are "managed," with governments intervening when they wish to influence rates operating under the loose intervention guidelines of the International Monetary Fund; and this will continue to be the case under the agreements negotiated in Jamaica.

Flexible Rates for Developing Countries Themselves: Pros and Cons

It is important to consider briefly the issue of flexibility in the exchange rates of the LDCs themselves, although it is not the central issue to be taken up here. Several developing countries appear to prefer fixed rates among industrial countries but flexibility for their own rates. From their viewpoint, this combination would lessen the uncertainty associated with flexible rates among industrial countries and at the same time preserve their own freedom to stimulate exports and offset domestic inflationary policy, as illustrated most notably by the Brazilian "trotting peg." [See Development Digest, January 1975, page 15.]

There is much to be said for allowing flexibility of LDC exchange rates even if industrial country rates are to be fixed. The chronic malady of the LDCs' foreign economic activity has in many cases been the maintenance of unrealistic exchange rates in the face of high domestic inflation. In these circumstances the risk imposed on the exporter by infrequent but very large exchange rate devaluations--made finally inevitable by inflation--has contributed to the stagnation of export supply and hence to the "trade gap" that has hindered growth. Moreover, as more developing countries demonstrate success in aggressive export expansion by employing devaluation and other measures, the longstanding myth that devaluation will not benefit LDC balance of payments because demand for their exports is inelastic has been disproved by recent empirical studies.

There is, of course, a group of developing countries for whom devaluation

is anathema. They vehemently support unchanged parities in relation to their respective traditional industrial country trading partners in the belief that devaluation will do nothing to help their balance of payments, but will provoke inflation and worsen the terms of trade. In addition, there are often political considerations that rule out devaluation; authorities in some LDCs fear that devaluation would demonstrate loss of government control, and would shake confidence of foreign investors and precipitate capital flight. Countries such as Mexico (until 1976), some Central American countries, India, and many African countries apparently subscribe to this view. On the other hand, several major developing countries have turned to flexible or quasi-flexible rates, including Brazil, Colombia, Indonesia, Korea, Malaysia, Morocco, the Philippines, and Yugoslavia. It is true that rates in most of these countries do not float freely; they are managed by the monetary authorities and changed gradually (under "crawling peg" or "trotting peg" adjustment). LDC economies are generally subject to more nonmarket control and government interventions than industrial countries; they tend to have greater export price fluctuations, and more severe shocks to their foreign sectors when particular policies are changed. The temporary swings associated with pure floating would thus seem to constitute a greater danger for LDC exchange regimes than for those of developed countries. The main utility of flexibility for these LDCs, then, is more likely to be that the crawling peg system can maintain constant real export and import incentives in the face of domestic rates of inflation different from the average for the rest of the world.

In relation to the major issues discussed below, an important problem confronting LDCs as a result of more flexible exchange rates among the major world currencies is how to respond to this flexibility in the setting of their own exchange rates. In view of the generally favorable effect on the foreign sector of greater flexibility in their own rates in these countries, it would represent a step backward if monetary reform measures seeking a return to a par value system forced LDCs to return to more rigid exchange rates than is now the case. However, the precedent of examption or nonreciprocity for LDCs in other contexts, such as in past and current trade negotiations within the General Agreement on Tariffs and Trade and the generalized system of tariff preferences, could be invoked to permit exemptions from such rules for the LDCs.

Flexible Rates among Developed Countries: Consequences for LDCs

The developing countries have generally opposed greater exchange rate flexibility. Historically, they appear to have identified "flexibility" with the probable devaluation of the pound if it were permitted to float. As a consequence, many Commonwealth countries anticipated that such an occurrence would reduce the real value of their export earnings from commodities whose prices were quoted in sterling. During the monetary crises

and eventual realignment of 1971, the LDC reaction was more generally one of frustration at exogenous shocks imposed on them by shifts in major currency parities. LDC representatives at international meetings, including the third meeting of the United Nations Conference on Trade and Development (UNCTAD III), emphasized their countries' loss of real value of dollar reserves, as well as sterling reserves (which had in vain been given a dollar parity guarantee), and the rise in dollar costs of imports from Japan and Europe. The same spokesmen were undoubtedly aware of, but made little reference to, the decline in real value of their outstanding debt denominated in dollars, nor did they foresee any compensating increases in dollar prices of their commodity exports.

When discussions on monetary reform began in 1972 in the Committee of Twenty, LDC participants tended to support fixity of exchange rates. This position was no doubt influenced by their concern that greater flexibility meant greater uncertainty generally, which made their own monetary and development planning decisions more difficult. Yet the general floating of exchange rates and the rapid inflation of 1973 appear to have made the modest increments in flexibility considered in the formal reform proposals look quite tame by comparison. By the time of the 1973 IMF and World Bank annual meetings, LDC opposition to increased flexibility in a revised system appeared to have weakened. Despite the persistent ongoing fears of the LDCs that a world system of flexible, and especially floating, rates would have negative effects on their economies, in the end their negotiators went along with the incorporation of flexible rates into accepted practice under IMF rules. By the time of the Jamaica meeting in 1976, the opposition had diminished further.

The theoretical arguments put forward by those opposed to greater exchange rate flexibility among industrial nations because it might be detrimental to the interests of the LDCs are: (1) it would increase uncertainty about real export earnings, import prices, and foreign exchange reserve values; (2) it would lead to greater commodity price fluctuations; (3) it would encourage the formation of currency blocs and might thereby inhibit the diversification of LDC trade from traditional trading partners; (4) it would raise problems for reserve and debt management. After examination of these issues, I have concluded that these fears generally warrant little weight compared with the overriding factor of potential improvement in LDC exports and economic activity to be expected from the improvement in the world trade and financial system that could follow from more flexible exchange rates.

The Uncertainty Issue. A central theme of the opposition of LDCs to greater exchange rate flexibility among developed countries is that the change would increase uncertainty. However, the general issue of increased uncertainty about export and import prices cannot meaningfully be analyzed by comparing a system of flexible exchange rates against one of eternally fixed, unchanging exchange rates. The latter is not a realistic option. In an ideal world with perfect upward and downward price and wage flexibility and smoothly functioning compensatory financing among countries, perpetually fixed exchange rates might be possible, and they would provide

complete certainty about the foreign exchange rate. But in the real world these conditions are not met; indeed, the attempt to hold exchange rates perpetually fixed would most probably require domestically unacceptable recessionary measures in deficit industrial countries, which if adopted would injure exports from developing countries. The choice is therefore not between permanently fixed exchange rates and flexible rates. It is between fixed rates with infrequent but large disruptive exchange rate realignments, and a system with more frequent but smaller rate changes. If it could be guaranteed that over a span of time the frequent smaller changes would constitute greater fundamental stability than that associated with the alternative of periodic large jumps of fixed rates, there would be a strong case favoring flexible rates over fixed rates to obtain the objective of reduced uncertainty.

A crucial issue is therefore whether the magnitudes of variation in exchange rates under flexibility will in fact be smaller than those associated with extended periods of fixed rates ending in major realignments. The empirical evidence on exchange rate variability under fixed and floating rates is shown in Table 1 for the period between 1959 and 1975.

Table 1. Mean, Standard Deviation, and Coefficient of Variation of Selected Currencies in Relation to the Dollar, 1959-75

Period and statistic	*Germany (deutsche mark/ dollar)*	*Japan (yen/dollar)*	*Britain (dollar/ pound)*	*France (franc/ dollar)*
Period of fixed rates, 1959:1–1973:1				
Mean	3.870	353.38	2.654	5.019
Standard deviation	0.305	19.94	0.188	0.235
Coefficient of variation	0.0789	0.0564	0.0707	0.0468
Period of floating rates, 1973:2–1975:1				
Mean	2.497	282.15	2.401	4.500
Standard deviation	0.130	12.47	0.077	0.275
Coefficient of variation	0.0519	0.0442	0.0321	0.0612

Source: Calculated from International Monetary Fund, *International Financial Statistics*, selected issues, end-of-quarter spot rates.
a. Based on quarterly data.

Since February 1973 the major currencies have been in a regime of managed floating. This period may therefore be considered as the reference period for data on the variability of floating rates. Fixed rates on the other hand extend back to the Bretton Woods agreements. However, a reasonable beginning date for examination of fixed rates is 1959. Prior to that year there was widespread use of exchange controls even for European currencies, so that the performance of fixed rates is most accurately shown in the period following 1958. For the terminal point of the period of fixed rates the first quarter of 1973 is the reasonable demarcation. Hence, two major jolts--the Smithsonian realignment of rates in December 1971 and the February 1973 dollar devaluation--are appropriately included within this

fixed-rate period. Indeed, the purpose of testing the degree of exchange rate variability under fixed versus flexible exchange rate regimes would be lost if the wrenching adjustments at the end of a long period under fixed rates were excluded from the measurements for the period of fixed rates, since inflexibility is in large part responsible for those jolts.

The data on the mean, standard deviation, and coefficient of variation (ratio of standard deviation to mean) for the dollar values of the deutsche mark, yen, pound, and franc during the fixed and floating exchange rate periods are given in Table 1. They indicate that, contrary to the popular impression, there were smaller underlying fluctuations during the period of floating rates than during the extended fixed-rate period. Except for the franc, the coefficient of variation is higher for the fixed-rate period than for the floating-rate period. The data are for spot rates at the end of each quarter. This length of period for each observation is reasonable for assessing the variability of rates as viewed by producers and purchasers making decisions on production, imports, and exports. Similar results are obtained when monthly observations are used (day-by-day fluctuations are of little significance). Since experience with floating is quite limited to date, it would be inappropriate to interpret these results as conclusive evidence that floating generates greater fundamental certainty (that is, less fluctuation) than fixed rates; a longer period of floating will be required. But clearly the evidence to date does contradict the general perception that floating rates have been more volatile than fixed rates. Moreover, the comparison is probably unfair to floating rates, for the following reasons: the experience begins from a base of disequilibrium in the foreign exchange markets; in this initial "learning" phase of early experience with floating, volatility was likely to be higher than might be expected later when exchange traders have become more familiar with floating and exchange markets become more fully developed; and the heavy strains placed on the exchange markets by the 1973 oil price rise constitute another handicap imposed on the monetary system during the period of observations on floating rates.

As risk averters, the LDCs should prefer frequent small changes in the exchange rates of developed countries over infrequent but very large changes. Preliminary evidence suggests that the variation in rates under floating has indeed been smaller than the shocks experienced under fixed rates, even with the severe strains on exchange markets in the 1973-74 period due to oil prices. Nevertheless, it is too early to reach a reliable conclusion on the relative volatility of floating versus fixed rates.

Another important aspect of uncertainty concerns speculative capital flows, a dimension of "disruption" that is not apparent if exchange rates alone are examined. Large, infrequent changes in par values encourage disruptive speculation, because of the "one-way bet." Sufficiently small and frequent changes minimize these disruptive flows. To be sure, any injury suffered by LDCs from these flows is only indirect since the speculation involves "hot money" moving among industrial countries but not into LDCs. Nevertheless, the complex of capital controls and distortions in monetary policy resulting

from attempts by industrial countries to control these movements is bound to inhibit the smooth expansion of markets for exports from the LDCs.

Another approach to the uncertainty issue concerns the relationship of inflation to exchange rates. It should be reasonable to expect changes in exchange rates among industrial countries to be within the same orders of magnitude as their differences in inflation rates. Therefore, any uncertainty accompanying more flexible rates should merely replace uncertainty previously associated with differential inflation rates, causing no increase on balance in the uncertainty facing LDC planners. Indeed, if the flexibility behaves in strict adherence to constant "purchasing power parity," the underlying uncertainty is even reduced by the move to flexibility, since the real cost of imports from a given country is held constant as movements in the exchange rate exactly offset price movements.

Commodity Price Fluctuation. A more specific fear of the LDCs is that more flexible exchange rates will lead to greater fluctuations of already unstable commodity prices. To put this argument in perspective it must be recognized that the magnitudes involved are not large. Consider, for example, the sizable exchange rate realignments of December 1971 that led the LDCs as a group to experience approximately a 4 percent depreciation in rates vis-a-vis those of the industrial countries. This change was quite limited when compared to the actual price fluctuations of individual commodities attributable to specific supply and demand developments for each good. For example, during 1972, selected dollar price changes were: cocoa, 19 percent; coffee, 12 percent; copper, -1 percent; cotton, 6 percent; fishmeal, 43 percent; rice, 13 percent; rubber, no change; sugar, 13 percent; tea, no change; tin, 8 percent. Changes in 1973 and 1974 were even larger. Hence the purchasing power value of individual commodities would very probably be much more influenced by their specific supply and demand situations than by exchange rate fluctuations in a more flexible system. Such rate changes in any event would presumably be less pronounced than the Smithsonian realignment, which terminated a long period of frozen rates.

Much of the concern about the effects of flexible exchange rates on commodity price fluctuation appears to assume that the price of the good (say, coffee) in the currency of normal quotation (dollars) would remain unchanged even though the currency devalued, thereby imposing a real price decline on the commodity. Furthermore, some LDCs appear to have held the view that since many commodities are quoted in pounds or dollars, and since these two currencies in recent years have been expected to depreciate once greater flexibility were an option, real commodity prices would be bound to fall along with them. But this result has not occurred: the virulent commodity price inflation of 1973-74, during a period of decline in these two currencies, belied this assumption. The premise also fails to stand logical scrutiny. Suppose, for instance, that the dollar depreciates in terms of the franc; then if coffee is quoted in

dollars its real price to the French declines, bidding up French demand; this increase in French demand boosts the dollar price, producing a price movement offsetting the depreciation of the dollar. The presence of a cartel should not change this effect. Suppose producers cooperate to maintain a dollar price at a level above competitive equilibrium that maximizes revenue for the oligopoly exporters. Then in the face of a dollar devaluation, there is no reason to expect the "real" monopoly profit potential of the cartel to decline, so the producers should be able to raise the dollar price quotation sufficiently to offset the dollar's decline.

Currency Bloc Problems. Most observers appear to assume that in a system with flexible rates among industrial countries, each LDC is likely to peg its own currency to that of one of the developed countries. Such a practice could give rise to several types of problems: (1) An LDC could be forced by movements in the currency to which it is pegged--the "center currency"--to make appreciations or depreciations of its own currency that might be inappropriate for its own balance of payments situation. (2) Choosing the center currency would involve difficult political decisions for each LDC. (3) Pegging to a center currency would frustrate LDC efforts to diversify trade among new partners because of the greater exchange rate risk involved in exporting to countries with other currencies. (4) LDC attempts at regional economic integration could be frustrated if prospective members are pegged to different center currencies. (5) When LDCs peg to center currencies, greater rate flexibility among these currencies would tend to divide the world into trading blocs.

Data are presented below indicating that floating beginning in 1973 did not lead to the formation of currency blocs of important magnitudes; LDCs in franc or sterling blocs accounted for a very minor portion of trade. Almost all the currencies of other LDCs were pegged to the dollar, formally or indirectly (that is, pegged to the SDR which until June 1974 was pegged to the dollar), or were following flexible rate practices themsleves. Initial experience therefore contradicts the feared scenario of the trading world dividing up into major center-periphery blocs.

In an LDC's policy decision on exchange rate pegging practice, there are two obvious alternatives to simply pegging to the currency of the principal trading partner. First, and ideally, an LDC in a world of flexible rates could seek to maintain a target trade-weighted exchange rate. Thus, if the LDC wishes to avoid inappropriate depreciation (or appreciation) despite the fact that its principal industrial trading partner is depreciating (or appreciating), its monetary authorities should follow an intervention policy in which the change in the LDC's exchange rate would equal the trade-weighted average of exchange rate changes of all its major trading partners. It would be possible to make this approach more precise if the LDC had reliable knowledge of its trade elasticities with each partner.

A second basic alternative for the LDC would be to peg its currency not to a mother currency but to some international standard. Some LDCs have

essentially chosen this option by pegging to the SDR. As constituted until mid-1974, the SDR was in a straitjacket with the dollar except for a specifically declared dollar devaluation vis-a-vis the SDR (as in December 1971 and February 1973). In June 1974, however, the SDR was redefined to be a "basket" of major currencies. It seems very likely that in the future more LDCs will choose to peg to this more broadly based international unit of value. This would reduce or eliminate most of the problems anticipated by analysts if currency blocs are formed with LDCs pegging to a number of center currencies.

LDC Pegging Practice. An important area for empirical examination is the currency pegging practices of the developing countries since the Smithsonian realignment of exchange rates in December 1971. This evidence is relevant to the concern that exchange rate flexibility will carve up the trading world into blocs, with the dangers listed above. The pegging practices of sixty-one developing countries (with populations of over 2 million), at the time of the Smithsonian realignment and as of July 1973 and June 1975, show the following patterns.

1) In response to the 1971 realignment, the French African countries tended to remain pegged to the franc, British Commonwealth countries to the pound, and most other LDCs to the dollar. There were, however, numerous countries that pegged to the dollar despite their traditional membership in franc or sterling areas. LDCs remaining with the franc, pound, and gold represented 30 percent of total LDC import value of these 61 countries. A group representing 41 percent of import value remained at par with the dollar, while a third group of countries amounting to 29 percent of LDC import value adopted other responses, most of them devaluation beyond that of the dollar. 2) By mid-1973, the weight (by value of imports) of countries pegging to the dollar had considerably increased. Countries formally pegging to the pound and franc represented a total of only 8 percent of LDC import values, those with flexible rates 10 percent, those formally pegging to the dollar 51 percent, and those pegging to the dollar de facto (by pegging to the SDR or gold) 31 percent.

3) By mid-1975 many countries previously pegging to both the SDR and the dollar had been forced to choose between the two because of the divorce of the SDR from a dollar par in mid-1974. It is remarkable that the large majority of countries in this situation chose to peg to the dollar rather than to the SDR. Nineteen countries with diverse geographical locations opted for the dollar, whereas only four countries had moved to a peg to the SDR (and one of these, Malawi, had moved from the pound to the SDR rather than from the dollar). Flexible exchange rates had been adopted by eight LDCs by mid-1975, and another five were frequently adjusting rates pegged to the dollar and therefore had characteristics similar to flexible rates (frequent adjustments were typically applied to offset rapid domestic inflation). Fully two-thirds of import value was accounted for by countries pegged to the dollar, and the only other widespread practice was the use of flexible rates, representing 19.4 percent of LDC import

value. Of countries with populations of over two million, eight African countries remained tied to the franc, but their weight in LDC imports was a mere 2.4 percent; only India, Bangladesh, and Sri Lanka (with only 5 percent of LDC imports) remained tied to the pound; and the four countries pegged to the new SDR represented only 6.5 percent of LDC import value. In sum, actual experience with floating rates among industrial countries has not borne out fears that the trading world would be carved up into franc, pound, and dollar blocs.

Reserve Management. Flexibility of exchange rates among industrial countries adds to the complexity of reserve management for LDCs; countries must take into account the risk of exchange realignment in their choice of reserve assets. Dollar devaluations have, of course, highlighted this risk. In general, more flexible rates should reduce the need for reserves. In a system of exchange rates that are fixed for developed but flexible for less developed countries, saving from reduced reserves would be a distinct possibility. However, flexible rates for industrial countries might well increase LDC reserve requirements because of new needs to provide for temporary fluctuations in the real value of foreign exchange earnings.

Aside from decisions on the level of reserves, decisions on their composition would also be affected by greater flexibility. A reasonable principle to apply would be to hold a balanced portfolio of foreign currency assets as foreign exchange reserves. Empirical evidence on the composition of LDC foreign exchange reserves is not publicly available. Of $16 billion held by LDCs in foreign exchange reserves in mid-1971, only $6 billion could be positively attributed to dollar and sterling assets on the basis of U.S. and British financial statistics. The $10 billion difference seems to indicate that there may already exist substantially more portfolio diversification than is commonly assumed, and this tendency must have increased since mid-1971. A more satisfactory solution than diversification of foreign exchange holdings would be to make available an international asset such as the new SDR consisting of a basket of currencies, but with the additional advantage that it could be actively purchased and sold. (At present all SDR transactions are through the IMF, and a transaction arises only when a holder of SDRs wishes to "use" them for balance settlement.) Finally, it must be emphasized that the increased risk of holding foreign exchange reserves in a system of flexible rates cannot be criticized without taking into account the offsetting factor that such assets yield higher interest return than gold or the SDR, even after the increase in the SDR's interest rate from 1 1/2 percent to 5 percent in mid-1974.

Flexibility of exchange rates among industrial countries may add to the complexities of LDC reserve management. But it must be remembered that the real risk of holding foreign exchange reserves will be greater under a fixed-rate system than in a flexible-rate system if, as seems likely, the fixed rates finally collapse in large, rending readjustments after prolonged periods, whereas flexible rates move much more moderately though more frequently.

Problems for Debt Management. Flexible exchange rates among developed countries may change the real value of foreign debt contracted by LDCs. In the 1971 and 1973 dollar devaluations, LDCs with debt denominated in yen or European currencies suffered losses; but these losses were much more than offset by windfall gains caused by the decline in the real value of dollar-denominated debt. A major consideration is the erosion of the real debt burden by ongoing inflation in the creditor country, quite apart from exchange realignment. Recent inflation rates have made even "hard term" loans to LDCs practically free of real cost. However, exchange rate movements under a more flexible system would partially substitute for differential inflation rates among developed countries. One risk, in fact, would be substituted for another. With respect to debt management, LDCs could lessen prospective shocks from rate realignments by contracting their debt among industrial creditor countries in proportions similar to those of their export trade shares. The result would be that an increased real debt service burden on the portion of debt held by an industrial country with appreciating currency would tend to be covered by increased earnings of the export sales to that country.

Predictions of specific "injuries" to the capital market have been made. Mundell, for instance, has argued that flexible rates among developed countries will increase the cost of capital to LDCs, because potential lenders will demand higher-risk premiums in their decisions to lend abroad to cover greater exchange risk. It would seem that the validity of this argument once again hinges on whether increased frequency of rate changes will lessen magnitudes of shifts sufficiently to reduce, rather than raise, overall exchange rate uncertainty of flexible system compared to a fixed-rate system.

Empirical Evidence

The robust trade performance of developing countries since the major currencies began to float has contradicted the expectation of injury to the LDCs from a system of flexible rates. Losses in real value of dollar reserves held by LDCs have been minor and have been offset by gains from the reduced real burden of dollar-denominated debt.

If flexible exchange rates among developed countries are considered detrimental to LDCs, then LDC export growth would have been expected to suffer and its relative importance to decrease in 1972 after the Smithsonian realignment of exchange rates among the industrial nations, and to decline still more beginning in 1973 when industrial countries' currencies started floating. Between 1967 and 1971 exports from developing countries, excluding oil exporters, grew somewhat more slowly than those from industrial countries; the average growth rate of the former over these years was less than four-fifths the rate of the latter. The relationship reversed in 1972: LDC exports grew faster than those of advanced countries, contrary to the hypothesis that they were injured by the Smith

sonian changes. During 1973 and 1974 dollar export values mushroomed by enormous proportions for all countries. LDC growth was once again greater than that of industrial nations, and the export growth of oil-exporting countries, of course, grew by much greater proportions. [Explanations omitted from this extract.]

Following the Smithsonian realignment of exchange rates there was considerable publicity about its effects on the developing countries. At UNCTAD III in 1972, LDC participants drafted resolutions that charged damage from loss of dollar reserve value and deterioration in terms of trade, and they demanded compensation. In fact, there were both positive and negative effects for the LDCs resulting from the December 1971 and February 1973 dollar devaluations.

The positive effects included: (1) an increase in the real value of LDCs' reserves held in gold or in appreciating foreign currencies; (2) a decrease in the real value of outstanding foreign debt denominated in dollars; (3) a probable rise in the dollar quotations of commodity prices in reaction to the initial decline in the real price of commodities traded with dollar price quotations; and (4) the expectation that the effective devaluation by the many LDCs maintaining parity with the devalued dollar would stimulate their exports, reduce their imports, and relax foreign exchange constraints on their domestic growth.

The negative effects were: (1) reserves held in dollars lost purchasing power; (2) the real cost of the repayment burden of debt denominated in appreciating currencies, such as the yen and deutsche mark, increased; and (3) imports from countries with appreciating currencies became more expensive in terms of the dollars earned by LDCs.

The IMF has estimated a number of these effects for both of the dollar devaluations. Although details of these calculations are not publicly available, the results, presented in Table 2, appear to be reasonable. The estimates imply that the LDCs were not on balance injured by the dollar devaluations. Their gains through reduction in real value of foreign debt offset their losses through decline in purchasing power of dollar reserves. IMF predictions of improved trade balances were at least consistent with the strong export performance of the LDCs in 1972 and 1973. It is true that LDC terms of trade deteriorated slightly as a result of the devaluation (that is, devaluation partially dampened commodity price rises, according to the IMF calculations). However, that result in part reflected the countries' own decision to devalue and to stimulate their trade balances. There will typically be welfare gains for the developing country resulting from trade balance improvement, because the scarcity value of foreign exchange to its national product usually exceeds that indicated by the market exchange rate. Moreover, increased exports afford the opportunity for increased utilization of underemployed labor in an LDC as well as the increased exploitation of economies of scale. Therefore, it is possible and even likely for these

welfare gains to have more than offset the welfare loss from any terms of trade deterioriation associated with dollar devaluations.

Table 2. Economic Effects of the 1971 and 1973 Dollar Devaluations on Selected Economic Variables for Less Developed Countries
(Percentages)

Effect	*December 1971*	*February 1973*
Average appreciation of LDC currencies vis-à-vis the dollar	4.0	5.0
Average depreciation of LDC currencies relative to those of all industrial countries	4.5	2.0
Deterioration in terms of trade	1.0[a]	0.5[a]
Induced average rise in U.S. dollar prices of LDC exports and imports	7.4	7.0
Rise in dollar value of LDC reserves	5.0	5.0
Decline in purchasing power of LDC reserves	2.3[b]	2.0
Rise in dollar value of debt		
All LDCs	4.5–5.0	5.0
Africa	n.a.	6.5
Latin America	n.a.	4.0
Decline in real value of debt	1.0–1.5[b]	1.5–2.0
Probable induced change		
In import volume	−2.0[a]	−1.0[a]
In export volume	1.5–2.0[a]	1.0[a]
In trade balance	...[a,c]	...[a,d]

Sources: International Monetary Fund, *Annual Report of the Executive Directors for the Fiscal Year Ended April 30, 1973* (IMF, 1973), pp. 29–31; *Annual Report* (1972), pp. 22–23.
a. Hypothetical calculations requiring elasticity assumptions.
b. Approximately $500 million.
c. $1.5 billion to $2 billion.
d. $1 billion.

Conclusion

The empirical evidence indicates no significant welfare loss for the LDCs resulting from the December 1971 and the February 1973 dollar devaluations (since real debt declines equaled or surpassed real reserve losses), and export data suggest that these realignments as well as subsequent floating stimulated or at least did not inhibit LDC exports. Concern among LDCs about increased uncertainty under a flexible-rate system should be tempered with recognition of the fact that such a system may be fundamentally more certain than a fixed-rate system with infrequent but very large exchange rate moves. Indeed, measures of exchange rate fluctuation among industrial nations indicate greater variability during the fixed-rate period 1959(I) to 1973 (I) than during the floating period thereafter. Nor is there a logical basis for the fear that greater rate

flexibility would provoke greater real commodity price fluctuations. The concern that flexible rates would carve up the trading world into blocs is unjustified both theoretically (an LDC can adjust its exchange rate by a trade-weighted average of its partners' rate changes) and empirically (the period of floating since 1973 did not witness substantial formation of such blocs). Floating in 1973 led to four main practices: pegging to the dollar, pegging to the SDR (and therefore the dollar before June 1974), and, though substantially less important, flexible LDC rates and pegging to the pound or franc. By mid-1975 by far the dominant practice was pegging to the dollar, and surprisingly few LDCs were pegging to the new SDR composed of a basket of currencies--although it is reasonable to expect that more will do so in the future. Finally, several LDCs with flexible rates are likely to maintain such rates to neutralize their greater-than-average inflation.

LDCs can diversify both their reserves and debt portfolios to reduce exchange rate risks (taking into account the country composition of their trade). LDC traders can utilize forward exchange markets in industrial countries if they wish to hedge against relative movements in major currencies; and LDC governments should be able at little cost to supply forward local currency cover for future export earnings (though not foreign cover for future imports, which themselves need no stimulus or which can be increased by reduced protection if compensation for exchange rate risk is desired).

Most important, the orders of magnitude of all possible effects appear to be such that the LDCs have far more to gain from participating in the global benefits of a generally improved world monetary system than they have to lose through specific, indirect injuries caused by the adoption of flexible exchange rates by industrial countries. If ratified by national legislatures, the monetary reform agreements of January 1976 will mean that countries will be free to continue pursuing the flexible exchange rate policies adopted by the industrial nations and by some LDCs in the previous three years, although perhaps with more systematic coordination and intervention to smooth out fluctuations in rates. Whether this experience will prove beneficial or injurious to the LDCs will hinge not on any side effects specific to them but on whether the allowance for flexibility provides a better basis for the international monetary system overall than the alternative system of par values changed infrequently but by large amounts.

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Indian Exchange Rate Policy Under Floating Rates

Satyendra S. Nayak

[Under the uncertain conditions of the 1970s, India's foreign exchange policies have been reasonably successful; exports have grown and gone into new markets, and crises were avoided. However, a shift in the intervention currency seems to be indicated.]

The system of floating exchange rates has presented a difficulty to the developing nations. Unlike the economies of advanced non-socialist nations, the economies of most developing nations are not very open. There are numerous restrictions imposed on trade and capital transactions in the balance of payments. The trade gap which they face is very much structural, arising from development requirements for imports which are greater than their export capability. They seek to fill this trade gap by inflows of external capital from multinational development agencies and from foreign governments. The volume and pattern of their imports are not so much determined by the market forces in their economies as by the strategy and policy of development they adopt. Given the policy-determined character of both the level and structure of imports, the movements in exchange rates have a lesser role in influencing them than in the more open economies of advanced nations. At the same time, the developing nations cannot contemplate keeping their exchange rates fixed when the major currencies are floating. Their objective is to keep the fluctuations in the exchange rates of their currencies vis-a-vis other currencies in as narrow a band as possible so

that the domestic cost of essential imports for which demand is relatively price-inelastic does not go up substantially.

If the depreciation of their currencies is likely to promote their exports and more than compensate for the rise in total import costs, such depreciation should be welcome. In this connection domestic supply elasticities of exportables also play an important role. The growth in exports due to competitive advantage gained in the world market through depreciation might be inhibitied by inadequate surpluses of exportables. The desirable range of fluctuations in the exchange rates of currencies would, therefore, depend upon the development strategy and policy that broadly govern the level and structure of imports, the structure of exports and its flexibility, and the size of exportable surpluses. The independent floating of their currencies is not advisable because of the fear of generating disequilibrating movements in the exchange rates.

In these circumstances the options open to them are to peg their currencies to either (1) a single currency, or (2) a basket of currencies, or (3) the Special Drawing Right. Which of these options is the optimal one for a particular country would depend upon the circumstances of each case. In addition to the factors already mentioned, other important ones are the currency through which the country's major trade and transfer transactions occur and the behavior of that currency in the foreign exchange markets. If developing nation's currency is pegged to a currency which is depreciating in the world exchange markets, the peg would be advisable if the advantages from export expansion exceed the disadvantages due to the increased costs of imports. If such a developing nation faces inflation which is internal in origin, the depreciation of the currency to which the developing nation's currency is pegged would restore the competitiveness of its exports in the external market. On the other hand, the prospects for expansion of exports might be limited, or domestic price stability might exist in a developing nation which could promote its exports without the need of depreciation of its currency. Under these conditions, the country concerned would be importing inflation from abroad if it has a fixed peg with a depreciating currency which increases the domestic cost of imports. It might be necessary to frequently revalue the domestic currency against the peg-currency in order to keep the exchange rates of the domestic currency vis-a-vis other currencies fairly constant and maintain the external value of the currency stable. Alternatively, the currency concerned might be pegged to a basket of currencies in which the weight of the depreciating currency remains small. Further, some developing nations which do not face a foreign exchange gap but enjoy export surpluses would find it convenient to peg their currencies to a currency which is appreciating so as to curb the domestic inflation caused by the export boom. Being pegged to an appreciating currency is bound to achieve an anti-inflationary impact. Therefore, the behavior of the

peg-currency or basket of currencies is an important consideration in determining the exchange rate policy of developing nations. The selection of the peg-currency--or currencies, in the case of a basket, and the weights assigned to them--should be such as to make the country's exchange rate policy consistent with the domestic and external economic objectives it seeks to achieve.

India and the Pound Sterling Peg

After the second devaluation of the Indian rupee in June 1966 until the breakdown of the Bretton Woods system in August 1971, India's exchange rate policy had not been the subject of as much debate and polemics as it had been during the early 1960's. But the 1971 suspension of the gold-US dollar convertibility and subsequent floating of the dollar and other major currencies necessitated a revision of India's exchange rate policy. At this juncture the government decided to peg the rupee to the US dollar, although the pound sterling continued to be used as an intervention currency. An intervention currency is a foreign currency which the central bank of a particular country uses to buy and sell at a fixed rate with respect to the domestic currency. Under the system of floating rates, when a central bank buys as well as sells only this currency at a fixed rate vis-a-vis the domestic currency, its exchange rates against all other currencies are determined by the behavior of the intervention currency against those currencies.

In an attempt to go back to the system of fixed but flexible rates an agreement was reached in December 1971 at the Smithsonian Institution on the realignment of exchange rates. Under the agreement, the US dollar was devalued by 7.9 percent. After devaluation, the dollar-sterling central rate came to be fixed at $2.6057. With the Smithsonian decision, the government of India chose to revert to pegging the rupee to sterling. But the rupee had been devalued against the pound by 5.3 per cent, and the central rupee-sterling rate was fixed at Rs 18.9677 as against the previous rate of Rs 18.00.

During 1972 Britain's balance of payments situation started worsening and pressure on sterling became evident in the foreign exchange markets. As a solution, Britain decided to float the pound on June 23, 1972, which then fell from the Smithsonian rate of $2.6057 to $2.4430. Since the Indian rupee was pegged to the pound, the exchange rates of the rupee with all other currencies came to be determined every day by the previous day's noon London market cross rates, so the rupee also depreciated. On June 26, 1972 the rupee was slightly revalued by reducing the central rate to Rs 18.95 from Rs 18.9677. It was further revalued by 0.89 percent on July 4, 1972 when the rupee-sterling rate was fixed at Rs 18.80.

The US dollar was further devalued by 10 percent on February 12, 1973. The pound sterling appreciated against it and so did the Indian rupee. Appreciation of the pound against the dollar was unfavorable for Britain's external payments position, which began to deteriorate. Deficits were large through 1975, and the external value of the pound sterling in the foreign exchange markets fell to $2.2825 in June 1975. From July 4, 1972 the rupee-sterling rate was maintained at Rs 18.80 until July 2, 1975, so the rupee also underwent depreciation to the same degree vis-a-vis other currencies. Table 1 shows the variations in the exchange rates of the rupee against eight important currencies between June 1971 and June 1975. It depreciated against the Belgian franc by 57 percent, against the D-mark by 65 percent, against the French franc by 53 percent, against the Italian lira by 11 percent, against the Japanese yen by 35 percent, and against the Canadian and U.S. dollars by eleven percent.

Table 1: Exchange Rates of Rupee During Pound Sterling Peg

(Rs per unit of foreign currency)

	1971		1972		1973		1974		1975	Depreciation
	June	Dec.	June	Dec.	June	Dec.	June	Dec.	June	of Rupee over period. (%)
Belgian franc (10)	1.50	1.66	1.77	1.82	2.02	1.96	2.69	2.19	2.36	57.33
D-mark	2.13	2.27	2.46	2.50	3.00	2.99	3.08	3.28	3.52	65.26
French franc	1.35	1.42	1.55	1.56	1.77	1.72	1.63	1.78	2.06	52.59
Italian lira (1000)	11.90	12.51	13.36	13.75	12.32	13.31	12.15	12.26	13.17	10.67
Japanese yen (100)	2.08	2.36	2.58	2.66	2.75	2.89	2.77	2.68	2.81	35.10
Pound Sterling	18.00	18.97	18.95	18.80	18.80	18.80	18.80	18.80	18.80	4.44
Canadian dollar	7.27	7.40	7.87	8.05	7.29	8.13	8.09	8.17	8.03	10.45
US dollar	7.44	7.43	7.76	8.01	7.28	8.09	7.87	8.07	8.24	10.75

Considering the share of India's trade with each one of the above countries as the weights, the effective depreciation of the Indian rupee during the three years from July 1972 to June 1975 was 22.57 percent.

Shift to Secret Basket

Until August 1974, during which period inflationary pressures were severe in India, this indirect depreciation of the rupee helped to maintain the competitiveness of our exports in the world market. By October 1974 the wholesale price index began showing a downward trend. The trend continued in 1975. The establishment of domestic price stability necessitated the maintenance of stability also in the external value of the rupee. Fresh thinking was needed in respect of exchange rate policy in the light of the changing domestic economic scene as well as the performance and future of the pound sterling.

The government of India decided to abandon the pound sterling as the peg-currency and pegged the rupee to a basket of currencies. The currencies included in the basket, and the weights assigned to each, have not been disclosed. Nevertheless, the pound sterling continued to be used as an intervention currency. The result of this policy was that although the rupee was pegged to the basket, the day-to-day fluctuations in the exchange rates of the rupee vis-a-vis other currencies continued to be governed by the London market cross rates for the pound sterling vis-a-vis other currencies. And even after shifting to the basket, the rupee continued to depreciate due to the depreciation of the pound sterling against major currencies. On September 25, 1975, when the rupee was pegged to the basket, the new central rate fixed against the pound sterling was Rs 18.3084, while the previous rate was Rs 18.60. Because of the persistent depreciation of the pound sterling, rupee-sterling parity had to be changed eight times by September, 1976.

The revaluation of the rupee against the pound sterling appears to have been such as to have kept the Rs-US dollar rate stable. During this period, the rupee was revalued vis-a-vis the pound sterling by 19.71 percent. Over the same period the pound sterling depreciated against the US dollar by 18.46 percent. Table 2 shows the exchange rates of the rupee vis-a-vis eight important currencies between September 25, 1975 and September 29, 1976 on the dates when the rupee was

Table 2: Exchange Rates during the Basket Peg

(Rupees per unit of foreign currency)

	Sept 5,1975	Sept. 25,1975	Dec. 5,1975	March 8,1976	March 11,1976	April 3,1976	April 23,1976	May 26,1976	Sept. 21,1976	Sept. 29,1976	Depreciation (-)or Appreciation (+)over period(%).
Belgian franc(10)	2.29	2.24	2.26	2.32	2.83	2.32	2.32	2.29	2.37	2.36	- 5.36
D-mark	3.41	3.38	3.41	3.55	3.51	3.56	3.56	3.50	3.64	3.65	- 7.99
French franc	2.00	2.02	2.45	1.98	1.99	1.93	1.93	1.92	1.84	1.83	+ 9.41
Italian lira (100)	13.15	13.29	13.13	13.01	11.25	10.58	10.19	10.75	10.64	10.53	+20.77
Japanese yen(100)	2.96	2.95	2.92	3.03	2.99	3.02	3.01	3.02	3.13	3.13	- 6.10
Pound Sterling	18.60	18.30	18.12	17.75	17.25	16.90	16.50	16.00	15.40	14.60	+20.26
Canadian dollar	8.56	8.73	8.92	9.29	9.17	9.21	9.16	9.22	9.22	9.25	- 5.96
US dollar	8.82	8.94	8.96	9.13	9.02	9.03	9.02	9.03	8.98	8.98	- 0.45

revalued against the pound sterling. It will be seen that during this period the rupee appreciated against the French franc, the Italian lira and the pound sterling, and depreciated against the Belgian franc, the D-mark, the Japanese yen, the Canadian dollar and the US dollar. Between Septem-

ber 25, 1975 and September 29, 1976 there was an effective appreciation of the rupee of 3.72 percent.

Impact on Trade. Under the system of floating rates, the exchange rate policy pursued by the government of India caused the depreciation of the rupee vis-a-vis several major currencies and so eliminated or reduced the over-valuation which had previously existed. In spite of the high rates of inflation, India's exports during 1972/73 and 1973/74 had expanded by 23 and 28 percent, respectively (Table 3). In 1974/75 our exports rose by 31 percent. During this year the declining trend in domestic prices was an additional factor that gave a boost to the exports. India had achieved a trade surplus of

TABLE 3: INDIA'S TRADE BALANCE

(Rs billion)

	Exports (1)	Imports (2)	Trade Balance (1-2)
1969-70	14.13	15.82	- 1.69
1970-71	15.35 (8.6)	16.34 (3.3)	- .99
1971-72	16.08 (4.8)	18.25 (11.7)	- 2.17
1972-73	19.71 (22.6)	18.67 (2.3)	+ 1.04
1973-74	25.23 (28.0)	29.55 (58.3)	- 4.32
1974-75	33.04 (31.0)	44.61 (51.0)	-11.57
1975-76	39.42 (19.3)	59.18 (12.9)	-10.76

*Estimate

Note: The figures in parentheses show the percentage increase over the previous year.

Source: Report on Currency and Finance, 1974-75.

Rs 1.04 million in 1972/73. But for the oil crisis in January 1974, India would have continued to expand the size of its export surplus in the subsequent years. About 50 percent of the increase in India's import bill in 1973/74 and 1974/75 was caused by the quadrupling of crude oil prices.

The regime of floating rates helped India to not only expand its exports but also to diversify them. The share of some of the traditional items like tea, jute manufactures and iron ore in the total exports registered a decline over the period 1969/70 to 1975/76, and coffee remained fairly stable. In the case of oilcakes, sugar, cotton textiles, leather and leather manufactures and pearl and precious stones, the share in total exports showed a rise in one or more years, but remained stable in other years. A more persistent increase could be observed in the share of chemicals and machinery and transport equipment.

On the import side, it has been noted that the structure of Indian imports is policy determined. The sharp increase in the share of imports of cereals from 4 percent in 1972/73 to 16 and 17 percent during 1973/74 and 1974/75 respectively was the result of shortfall in the domestic output of foodgrains. The decline in the share of raw cotton from 6 percent in 1970/71 to 0.6 percent in 1974/75 occurred on account of improved domestic cotton production. The marked increase in the shares of mineral fertilizers should be ascribed to the price inelasticity of their demand, in spite of the

four-fold increase in their prices. The share of items like chemical elements and compounds, paper, paper board and its manufactures, non-ferrous metals and electrical and non-electrical machinery have remained more or less stable. It may be concluded that India's import structure is not susceptible to changes in exchange rates. It is governed by more basic and structured factors.

The value of India's exports to various countries and the share of each country in the total exports shifted between 1969 and 1975. The share of India's exports to USA fell from 17 percent in 1969/70 to 11 percent in 1974/75. During the same period the share of Japan declined from 13 to 9 percent, and the proportion of the UK also registered a fall from 12 to 9 percent. Russia's share remained more or less stable at 13 percent. Exports to Western European nations like France, Italy and West Germany increased. The share of Iran also jumped from 2 percent in 1969/70 to 7 percent in 1974/75. There has thus been some regional diversification of India's exports. India's reliance on a few countries like the USA, UK and Japan as the major markets for its exportables is gradually declining, as its exports to a large number of countries in Asia, Africa, and Latin America are slowly growing. The depreciation of the Indian rupee has enabled Indian exporters to compete effectively in these markets which were previously dominated by the advanced nations. The diversification of export markets appears to be one of the chief causes of buoyancy in India's exports since 1972.

Intervention Currency and the Foreign Exchange Portfolio

In view of the persistent decline in the external value of the pound since the beginning of 1975, serious thought needs to be given to the utility of maintaining it as the intervention currency. During the period of one year since the pegging of the rupee to a basket of currencies, the pound sterling fell from $2.0436 in September 1975 to $1.6675 on September 29, 1976, and the rupee was upvalued vis-a-vis the pound eight times. The question that arises is: as the pound sterling is weak and is likely to continue to be so for some time to come, what is the rationale behind maintaining it as an intervention currency? Since during the period of the basket peg, the Rs-US dollar parity has been maintained, there may be a case for shifting to the US dollar as an intervention currency. At present the US dollar is relatively strong in the foreign currency markets.

The external value of a currency that is selected as an intervention currency should be fairly stable. The main reason for this is that a substantial amount of foreign exchange reserves has to be held in the intervention currency. The details of our foreign exchange portfolio management are secret and it is not possible to say exactly what proportion of the total liquid foreign exchange reserves are held in the different currencies. However, there must have been a considerable loss of purchasing power of India's foreign exchange reserves held in sterling.

The arguments put forward for maintaining the pound sterling as an intervention currency are unconvincing. Indian foreign exchange dealers, it is true, have better communication with the London market than elsewhere. It is argued that the London market is the most efficient foreign exchange market and that, therefore, it is better to have the pound sterling as an intervention currency than any other. But the London market is an international market for all foreign currencies, and if India adopts the US dollar as an intervention currency the Reserve Bank and Indian foreign exchange dealers can deal as efficiently in US dollars in the London market as they can in the pound sterling.

Another argument is that India's sterling transactions are the largest among all the foreign currencies. However, invoices by exporters who were quoting in terms of sterling have now been gradually shifting towards the US dollar. At present it is estimated that only about 20 percent of exports are denominated in terms of the pound sterling, while over 50 percent of export transactions are quoted in US dollars. If the Reserve Bank starts operating in the US dollar, the risk of loss due to fluctuations in the exchange rate of the pound sterling will have to be borne by the foreign exchange dealers. Dealers in foreign exchange would cover the risk by entering into forward transactions. Since the Reserve Bank is already buying forward pound sterling, US dollar, D-mark and Japanese yen, a change of intervention currency from pound sterling to US dollar would not create any serious problem. The resistance to abandoning the pound sterling as an intervention currency appears to be entirely psychological. Under the system of floating rates, any country pegging its currency to any other currency or a group of currencies or the SDR has to keep its policies very flexible.

Conclusions. Under the regime of floating exchange rates which emerged in August 1971, the decision of the government of India to peg the rupee to pound sterling between December 1971 and September 1975 resulted in a backdoor depreciation of the rupee vis-a-vis the major currencies of the world by 23 percent. Until July 1974, due to the prevalence of inflationary conditions in the country, this depreciation proved to be a boon to Indian exporters who could maintain the competitiveness of Indian goods in the world market. It was one of the factors making for diversification of the composition as well as direction of Indian exports. But with the establishment of domestic price stability, and given the persistent depreciation of the pound sterling, the policy of pegging the rupee to a basket of currencies is rendered futile without the adoption of a stable intervention currency.

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